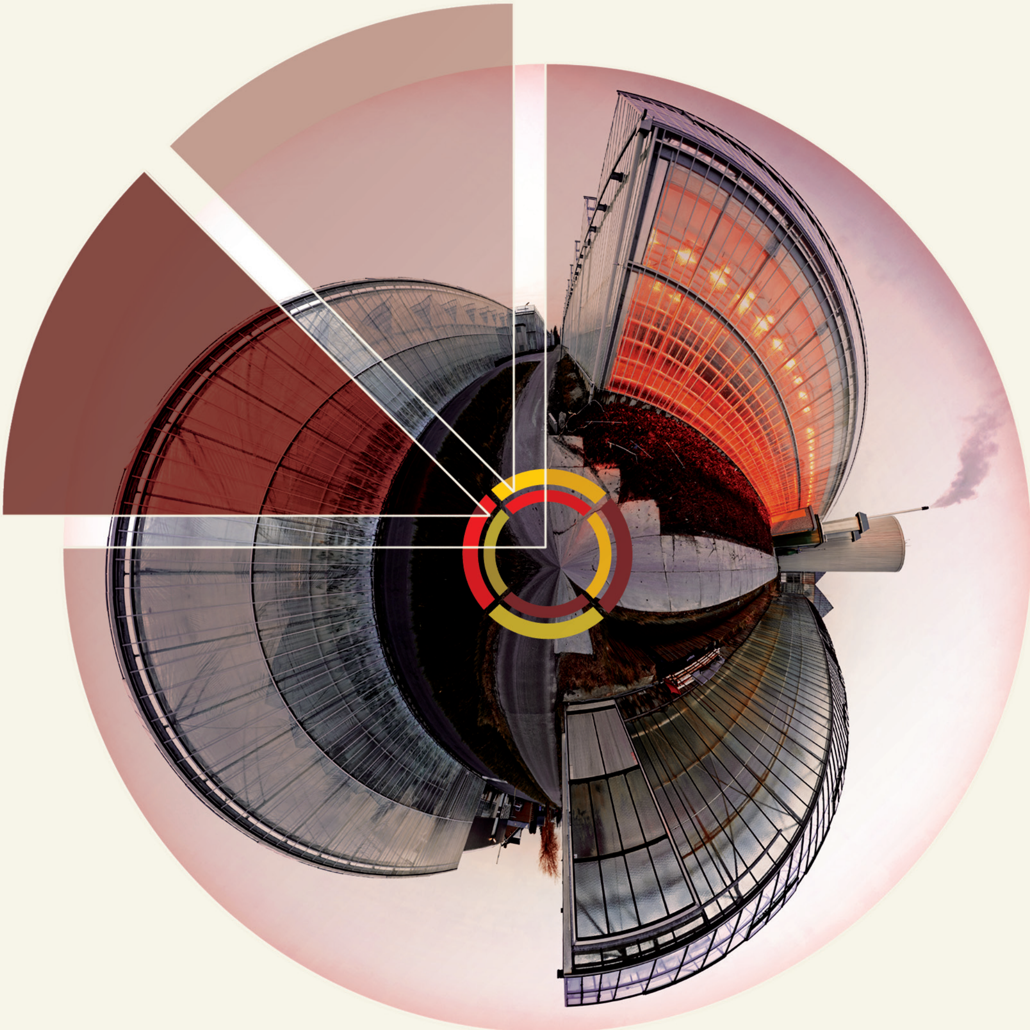
Economic analyses of the Dutch greenhouse chain in a changing environment



Daphne M.I. Verreth

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Abstract

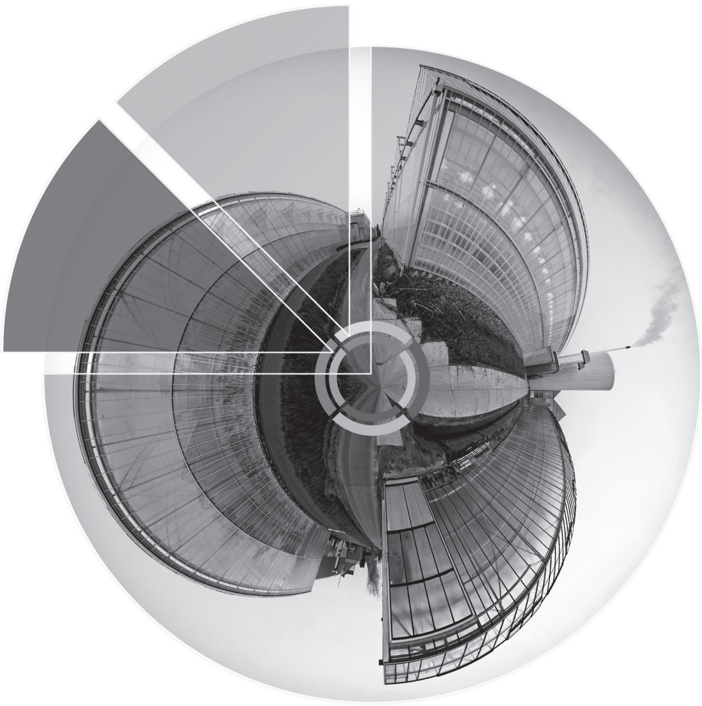
Horticultural greenhouse firms operate in a changing environment. This thesis has investigated the socio-economic consequences of market environment changes on supply, demand and prices throughout the Dutch greenhouse horticulture chain. The following market changes were studied: the increasing need for reducing fossil fuel use and CO_2 emissions, the on-going consolidation among retail companies, and the increasing probability of health scares and border closures due to higher frequency of food safety hazards or reforms in trade regulations. Partial equilibrium models which dealt with these market environment changes, such as trade regulations, increasing market concentration and environmental changes, are reviewed. Subsequently, the economic consequences of the changes are examined.

The main findings indicate that partial equilibrium models of the horticultural sector focus on trade regulations and often ignore the impacts of market concentration and environmental concerns. A border closure negatively affects producers' welfare. On the other hand, retailers and consumers experience welfare gains if a border closure occurs. If consumer and export demand decline simultaneously with the occurrence of a border closure, then the producer prices decline more than three times than retail prices. No evidence for the presence of retail market power to wholesalers is found. However, the results suggest that in the Dutch onion industry, wholesalers exert market power over retailers.

To assess the economic consequences of changes in environmental regulation in the sector, this thesis analysed Dutch horticultural producers' behaviour and decision-making regarding energy use and investments in energy-related technology. Short- and long-term supply elasticities were estimated. The results show that it takes approximately two years to bridge half of the gap between actual and optimal levels of energy-related capital, which is a moderate adjustment period. If the total quantity of used (or demanded) energy decreases, more electricity will be produced and sold to the grid. Part of the required energy is produced by Dutch producers using energy-related equipment. Dutch producers are less vulnerable to a market change if they are able to diversify their output and sell, for example, electricity to the national grid.

Keywords: Horticultural greenhouse chain, market environment changes, market power, health scare, border closure, energy-related capital.

Contents



1

General introduction

1.1 Introduction

1

The Dutch greenhouse horticulture sector is of economic importance. The Netherlands has a world-wide leading position in the exports of greenhouse products. From the greenhouse vegetables produced in the Netherlands, approximately 80 percent are exported. Tomatoes, cucumbers and bell peppers are the three most important vegetables in terms of trade volume and production output, i.e. the latter for 46.9%, 24.8% and 21.0% respectively (CBS and LEI, 2012). Together with Mexico and Spain, the Netherlands belong to the top 3 tomato exporters in the world (Hollandtrade, 2011; Slagboom, 2011). For ornamentals, i.e. cut flowers and potted plants, the Netherlands accounts for almost 70 percent of European Union exports.

1.2 Problem statement

Greenhouse producers of fresh vegetables and ornamentals faced many challenges in recent years, such as the financial crisis in 2009 and the outbreak of the Entero-hemorrhagic Escherichia coli bacteria (EHEC) in 2011 (Engelenburg, 2012). Besides, the economic and institutional environment in which the Dutch greenhouse sector operates is changing. Examples are changes in the increasing need for reducing fossil fuel use and CO_2 emissions, and the on-going consolidation among retail companies. The changes in the horticulture greenhouse market have resulted in bankruptcy of many Dutch greenhouse firms which were not able to cope with the economic losses.

The Dutch greenhouse chain was strongly affected by the discovery of EHEC in fresh vegetables. As a result, Russia closed its borders for the majority of West-European vegetables, such as tomatoes, red peppers and cucumbers. In addition, consumer and export demand for these vegetables dropped due to a health scare effect. In the Netherlands, the EHEC outbreak caused a drop of approximately 5 percent in exports and Dutch wholesalers and producers suffered millions of euros of damage (Product Board Horticulture, 2011). Because of the increasing globalization of trade, health scares and border closures may happen more frequently in the future.

Dutch greenhouse producers also experienced difficulties with the changes in the agreements with the Dutch government in which objectives for energy saving and the production of sustainable energy have been set (the so-called Clean and Efficient Agri Sectors Agreement). The sector is the most energy-intensive sector in Dutch agriculture. Ten percent of the total gas consumption in the Netherlands is used for heating greenhouses. Because of its size and intensity of energy use, the government provided the sector subsidies and tax incentives to encourage greenhouse firms to invest in energy-saving equipment and sustainable energy innovations. Between 2000 and 2008, many greenhouse firms invested in combined heat and power equipment (CHP). CHPs enable producers to exploit economies of scope in producing electricity, heating and CO_2. Producers could sell the surplus of produced electricity to the national grid and could reduce the total amount of energy used within the firm. The Dutch greenhouse sector is thus also a major electricity producer and supplier. However, investment in CHP became unprofitable since the market price of electricity dropped and the gas price increased (Energy Matters, 2011; Postma, 2012).

Another example of the changing economic and institutional environment includes the consolidation of retail companies and the subsequent pressure of the retailers to upstream stages of the supply chain. The on-going consolidation in the retail sector raised retailer's possibility to experience lower costs and higher profits for their firms (Kaditi, 2011). In general, it is thought that the consolidation enables retailers to exercise buying and selling market power (Kaditi, 2011). In recent years, it has not been uncommon for the producer and wholesale prices of an agricultural product to fluctuate, while consumer prices hardly change (Sexton and Zhang, 2001; Vavra and Goodwin, 2005). Moreover, retail prices tend to respond more quickly and fully to producer price rises than to producer price drops (Borenstein *et al.*, 1997; McCorriston *et al.*, 1998; Meyer and von Cramon-Taubadel, 2004). The asymmetric price transmission between producers, wholesalers, retailers and consumers resulting from retailer or wholesaler concentration may have serious long-term effects on consumers and upstream suppliers (Sexton *et al.*, 2007). Based on simulation models, Sexton and Lavoie (2001) conclude that even modest levels of retail market power can have impacts on prices received by producers and paid by consumers (Réquillart *et al.*, 2008), and influence the outcomes of policy measures or produce trade distortions (Soregaroli *et al.*, 2011). Many retailers have centralized their purchase of foods and rationalized their supplies in shorter chains. In the consumer market of vegetables, the four largest retailers in the Netherlands have a market share of approximately 65–75 percent, whereas retail concentration tends to be higher on the purchase side (retail-wholesale link) (Bunte, 2009). The four largest wholesalers of fruit and vegetables account for approximately 50 percent of the market (Bunte, 2009; NMa, 2009). In the Dutch greenhouse vegetable supply chain, many producers join wholesale cooperatives which presumably represent the producers' interests in the market for fresh vegetables. Retail firms that exert market power to upstream stages or wholesale firms that exert market power to upstream or downstream stages, may cause asymmetric price transmission (Peltzman, 2000; Lloyd *et al.*, 2001).

Governments and other stakeholders increasingly perform ex-ante and ex-post assessments in order to evaluate policies and changes in the economy such as the one discussed above. Multiple methods are used to undertake ex-ante and ex-post assessments. At the chain level, the most commonly used approaches to quantify supply, demand and trade patterns in the market, are partial equilibrium and general equilibrium models. Partial equilibrium models are used to assess impacts on particular subsections of the economy by assuming that changes affect only those specific sectors of the economy (e.g., only the greenhouse sector), whereas computable general equilibrium models take the economic interactions between the entire macroeconomic system into account (van Tongeren *et al.*, 2001; O'Toole and Matthews, 2002). To focus on a single stage of the chain, such as the producer stage, it is helpful to include individual firm-specific characteristics. The energy and environmental changes in the Dutch greenhouse sector, such as the Clean and Efficient Agri Sectors Agreement and the increasing pressure to reduce CO_2 emissions, imply that total energy use by individual greenhouse firms should be reduced. This is possible by factor substitution between variable inputs or abatement activities. As a consequence, modelling the effects of environmental policies requires production and input levels of individual firms (Gardebroek, 2001).

The foregoing discussion shows that a major challenge faced by the Dutch greenhouse chain is to cope with these market environment changes: increasing globalisation of trade, increasing demand for sustainable production, the subsequent (technological) measures and covenants and, the potential imperfect competition throughout the chain. Globalisation of trade, for example, could increase the frequency of food safety hazards and subsequent border closures. To respond more effectively to these market environment changes, policy-makers and greenhouse interest groups can benefit from ex-ante assessments of the economic impacts of these changes.

1.3 Objective

The overall objective of this research is to analyse the effects of market environment changes in the Dutch greenhouse horticulture chain. More specifically, the thesis analyses the consequences of changes in regulations and agreements, or market structures on supply, demand and prices throughout the chain. Following the developments in the Dutch greenhouse chain, this thesis makes the assumption that the chain is characterized by imperfect competition. The main objective is separated into four sub-objectives:

1. to review existing policy analysis models in agricultural chains and identify the gaps in these models. The focus is on partial equilibrium models which deal with agro-economic policy analysis regarding the main market environment

changes in the horticulture greenhouse chain, i.e. trade regulations, market concentration and energy use and environmental issues;
2. to develop a partial equilibrium model, by accounting for some of the identified gaps found in sub-objective one, that is able to quantify the effects of health scares and border closures on supply, demand and prices in an imperfectly competitive Dutch greenhouse supply chain;
3. to examine the vertical price transmission in the Dutch vegetable market and infer whether price adjustments are asymmetric.
4. to analyse the greenhouse firms' decisions regarding energy use and investments in energy-related equipment.

In Figure 1.1, the conceptual framework of the Dutch horticulture greenhouse chain is presented, highlighting the sub-objectives of this thesis. The big frame represents sub-objectives one and two, which take into account the entire greenhouse chain, including international trade flows and the consumer stage. Sub-objective three focuses on the vertical price transmission of the Dutch greenhouse vegetable supply chain, including the import and export flows. Lastly, the inner box represents the focus at the producer stage (energy use and energy-related investments).

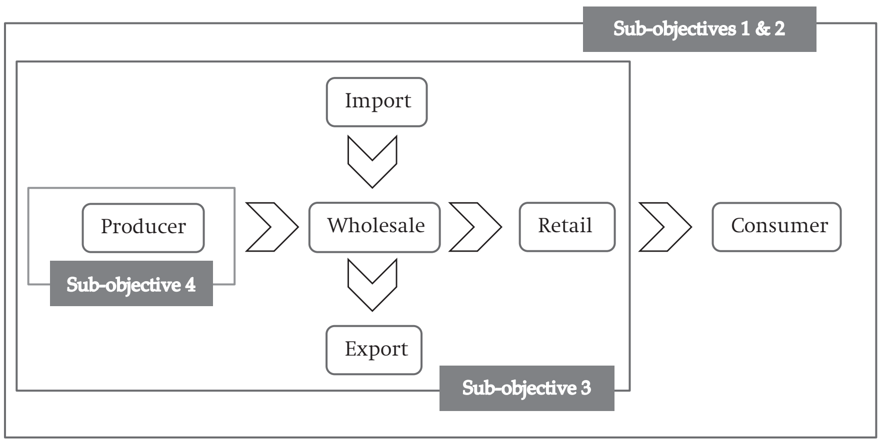


Figure 1.1 Conceptual Framework thesis

1.4 Outline of the thesis

The thesis presents analyses on economic and institutional environment changes in the Dutch horticulture greenhouse sector. The thesis is composed of a general introduction (**Chapter 1**), four research chapters (**Chapter 2, 3, 4, and 5**) and a general discussion (**Chapter 6**).

Chapter 2 provides an overview of the existing partial equilibrium models in the horticulture sector. This chapter reviews models that cope with changes in 1) trade regulations; 2) concentration in the chain; and 3) environmental changes in the greenhouse sector. The review examines the underlying assumptions and applied methodology, and defines possible improvements for future greenhouse partial equilibrium models.

Chapter 3 develops a partial equilibrium model to quantify the effects of exogenous shocks and market power at the retail stage on supply, demand and prices at the producer, wholesale and retail stages in the Dutch tomato chain. Thereafter, the model is used to simulate the short-term impacts of health scare and export closures in low and high production seasons for Dutch tomatoes. In addition, the implications of various combinations of market structures, such as perfect competition and oligopolistic market structure, on supply, demand, prices and total welfare are analysed.

Chapter 4 explores the vertical price transmission in the Dutch vegetable greenhouse sector, taking into account that wholesale or retail stages are characterised by buyer power. To do so, the chapter develops and estimates a theoretical model that describes the long-term relationships between domestic prices in all stages of the greenhouse vegetable supply chain (that is, producer, wholesale and retail prices) and includes the effect of international trade prices by means of time series models. Thereafter, the price series are tested for asymmetry.

Chapter 5 describes the behaviour of greenhouse producers regarding their output supply, energy use and investments in energy-related equipment. The behaviour of the firm is modelled using a combination of a dynamic cost function and a static profit function framework. The optimal quantity of energy use is derived from the link between these two functions. The model is applied to a panel of Dutch greenhouse firms, and takes into account that some Dutch greenhouse firms are, at the same time, electricity users and producers.

Finally **Chapter 6** discusses the overall results of the various studies described in this thesis in a wider context. Critical reflections and implications of the research are done and future perspectives are also presented.

References

Borenstein, S., Cameron, A.C. and Gilbert, R. 1997. Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes? *The Quarterly Journal of Economics* 112: 305-339.

Bunte, F. 2009. Prijsvorming glastuinbouw. Nota 09-02.Den Haag: Agricultural Economics Research Insitute (LEI).

CBS and LEI. 2012. Land- en tuinbouwcijfers 2012.'s-Gravenhage Statistics Netherlands (CBS); Agricultural Economics Research Instititute (LEI).

Energy Matters. 2011. Ontwikkeling barometer marktpositie glastuinbouw WKK (in Dutch).Energy Matters.

Engelenburg, H., 2012. Lichtpuntje voor de glastuinders. Het Financieele Dagblad. 5 December 2012.

Gardebroek, C. 2001. *Micro-econometric models for analysing capital adjustment on Dutch pig farms* (Wageningen, Wageningen University).

Hollandtrade. 2011. Horticulture is a mainstay of Holland's trade. Available at: "http://www.hollandtrade.com/sector-information/horticulture/?bstnum=4928" (last accessed 22 January 2013).

Kaditi, E.A. 2011. Market Dynamics in Supply Chains: The impact of globalization and consolidation on food Companies' mark-ups. LICOS Centre for Institutions and Economic. Discussion Paper 273/2011. Katholieke Universiteit Leuven.

Lloyd, T.A., McCorriston, S., Morgan, C.W. and Rayner, A.J. 2001. The impact of food scares on price adjustment in the UK beef market. *Agricultural Economics* 25: 347-357.

McCorriston, S., Morgan, C.W. and Rayner, A.J. 1998. Processing Technology, Market Power and Price Transmission. *Journal of Agricultural Economics* 49: 185-201.

Meyer, J. and von Cramon-Taubadel, S. 2004. Asymmetric Price Transmission: A Survey. *Journal of Agricultural Economics* 55: 581-611.

NMa. 2009. Prijsvorming in de agri-food sector. The Hague: Nederlandse Mededingingsautoriteit (NMa).

O'Toole, R. and Matthews, A. 2002. The IMAGE CGE Model: Understanding the Model Structure, Code and Solution Methods. Trinity Economics Papers.

Peltzman, S. 2000. Prices Rise Faster than They Fall. *Journal of Political Economy* 108: 466-502.

Postma, R., 2012. Toen onze paprika's nog de wereld overvlogen. NRC Handelsblad. 18 December 2.

Product Board Horticulture. 2011. Marktbeeld Tomaat.

Réquillart, V., Simioni, M. and Varela Irimia, X. 2008. Imperfect competition in the fresh tomato industry. Paper presented at: EAAE International Congress, Ghent, Belgium, August 26 - 29.

Sexton, R.J. and Lavoie, N. "Food processing and distribution: An industrial organization approach", in B.L. Gardner and G.C. Rausser (eds.), *Handbook of Agricultural Economics*: Elsevier, 2001, 863-932).

Sexton, R.J., Sheldon, I., McCorriston, S. and Wang, H. 2007. Agricultural trade liberalization and economic development: the role of downstream market power. *Agricultural Economics* 36: 253-270.

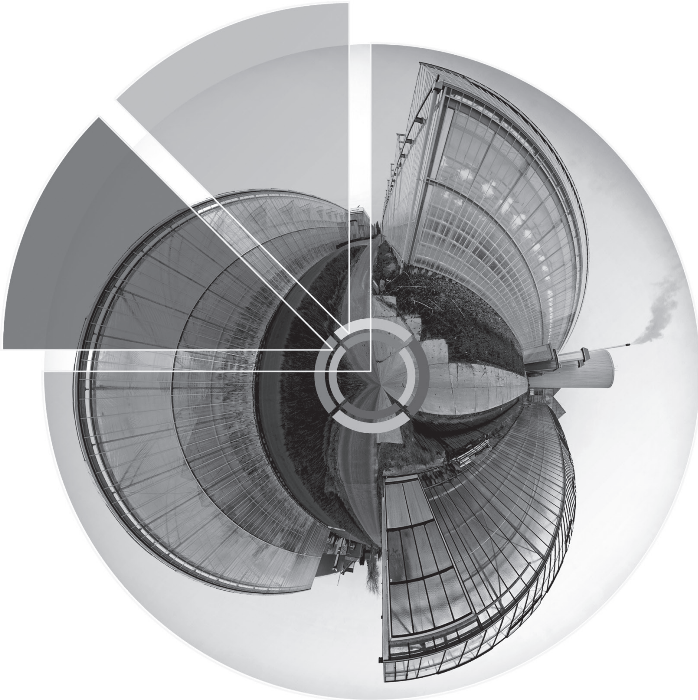
Sexton, R.J. and Zhang, M. 2001. An assessment of the impact of food industry market power on U.S. consumers. *Agribusiness* 17: 59-79.

Slagboom, E. 2011. Nederland blijft wereldtop met export verse groenten. Available at: "http://www.tuinbouw.nl/nieuws/persbericht-nederland-blijft-wereldtop-met-export-verse-groenten" (last accessed 22 January 2013).

Soregaroli, C., Sckokai, P. and Moro, D. 2011. Agricultural policy modelling under imperfect competition. *Journal of Policy Modeling* 33: 195-212.

van Tongeren, F., van Meijl, H. and Surry, Y. 2001. Global models applied to agricultural and trade policies: a review and assessment. *Agricultural Economics* 26: 149-172.

Vavra, P. and Goodwin, B.K. 2005. Analysis of Price Transmission Along the Food Chain. Food, Agriculture and Fisheries Working Papers. no 3.OECD.



2

Modelling market environment changes in the horticulture sector – A review

D.M.I. Verreth, F. Bunte, and A.G.J.M. Oude Lansink

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Abstract

The European horticultural sector faces changes in its market environment, such as changes in trade regulations, concentration in the chain, and environmental concerns. These issues may individually affect the future economic and environmental performance of horticulture. The objective of the present chapter is to review partial equilibrium models in terms of their ability to cope with the aforementioned aspects of the horticultural sector. We found that changes in trade regulations are already modelled in a detailed way in horticultural partial equilibrium models. However, chain concentration and environmental concerns are addressed to a much lesser extent in the currently available models.

Keywords: Partial equilibrium models; Trade regulations; Market concentration; Environmental issues; Economic models; Greenhouse sector.

2.1 Introduction

The horticultural sector is of great economic importance in the European Union (EU), because of its large value added and the employment opportunities it provides (Bogers, 2007). Nowadays, the European greenhouse industry faces many important challenges. These challenges are related to important changes occurring in market conditions, such as reforms in trade policies, the enlargement of the EU, and the increased demand for environmentally friendly and sustainable production. The changes in the market can be categorized into three types: (1) increased international competition arising from a growing global market due to new players and changes in trade regulations; (2) a high level of concentration among retailers and discount chains creating the conditions for exercising market power and an imperfectly competitive market; and (3) a growing public demand for sustainability and environmental regulations and standards which complicate the production environment for producers.

Collectively, the three types of changes may individually affect supply, demand and trade patterns in the market. To assess these impacts quantitatively, economic models are important tools. The most commonly used approaches for market level models are based on partial equilibrium (PE) and general equilibrium (GE) methodologies. On the one hand, PE models are used to assess impacts on particular subsections of the economy by assuming that changes affect only certain sectors of the economy. On the other hand, GE models attempt to describe and analyse the entire economic system, capturing not only the direct impact of a policy shock on the relevant market, but also the impact on other parts of the economy and feedback effects from these to the original market (O'Toole and Matthews, 2002). In this review, we focus on a small part of the total economy, the horticultural sector.

Although PE models do not account for as many linkages between product groups as GE models do, they can provide a transparent and focused analysis of how a limited number of products are affected by policies or changes in the market. PE models can analyse a wide variety of policies and are an appropriate tool for analysing the effect of the three categories of change the horticultural sector faces. In past decades, modelling economic issues in the horticultural sector resulted in a huge amount of articles. A review of the present state of PE models in the agricultural sector has already been performed (Conforti, 2001; van Tongeren *et al.*, 2001; Anania, 2006; Balkhausen *et al.*, 2008; Pérez Dominguez *et al.*, 2008). However, to our knowledge, a review of the present state of PE models in the horticultural sector has not been made. Therefore, this article attempts to review and summarise the models and approaches to develop a PE horticulture model which is able to cope with the three categories of changes in horticultural markets.

The chapter is organized as follows. The next section describes in more detail the three types of change in horticultural markets. This is followed by a review of current PE models which analyse these issues in the horticultural sector or the agricultural sector. The review looks at the assumptions taken, the methodology, and the possible improvements for horticultural PE models. The chapter ends with a conclusion and discussion.

2.2 Overview of Recent Market Changes in European Horticulture

Trade regulations

The volume and variety of fruit and vegetables traded globally has grown since the 1990s, at an average annual growth rate of 4 percent for both imports and exports. This growth is due to a rise in welfare, EU enlargement, improved technology, seasonal variation in production, and the consumer's demand for quality fruit and vegetables (Wu Huang, 2004). Fruit and vegetable trade has also grown as a result of trade liberalization and is expected to be fostered even further when an agreement is concluded in the Doha Round. The Doha Round, established by the World Trade Organisation (WTO), set limits on European and national policy freedom in the areas of market access, domestic support and export support. As part of the Doha Round, the EU has offered to reduce tariffs and trade distorting producer subsidies by 60 percent and 80 percent respectively, and export subsidies will be eliminated altogether (Huige *et al.*, 2010).

Trade policies, regulations and protocols developed at the global level and at the EU level, are applied among other things to protect domestic production. Growing regional and international trade agreements, an increase in negotiated bilateral free trade agreements, and further liberalization has led to lower barriers to trade (Wu Huang, 2004). For EU horticulture, the most important (trade) policy and framework is the CAP (Common Agriculture Policy) and its accompanying reformed CMO (Common Market Organisation) for fruit and vegetables. The CAP is an integrated system of measures which combines direct subsidy payments for crops and land. The CAP includes price support mechanisms such as import levies for specified goods imported into the EU, import quotas, 'set-aside' payments, enlarged tariff rate quotas (TRQs), entry price system (EPS), a Single Payment Scheme (SPS), and an internal intervention price. The reformed CMO aims to encourage producers to be more market-oriented. Main CMO trade instruments are the inclusion of fruit and vegetables in the SPS, and including export refunds and EU-financed withdrawals (except for free distribution) (CEC, 2007). Trade of fruit, vegetables and ornamentals is further regulated in the Agreement on

Sanitary and Phytosanitary Measures (WTO-SPS). This agreement aims to prevent disproportional import criteria and allow the right of every WTO member to set up (temporary) import requirements (Huige *et al.*, 2010).

Concentration among producers, retailers and discount chains

The food processing and retail industries have become increasingly concentrated in recent years (Sexton and Lavoie, 2001; Anders, 2005; Wijnands *et al.*, 2007). At the national level of the EU Member States, the four largest food retailers together hold domestic market shares of between 60-80 percent (Bunte, 2009). Concentration tends to be higher on the buying side rather than the selling side. The leverage that the retail food industry has over their suppliers has increased through the growth of private labels, their multiproduct nature and their control over shelf space. Moreover, food retailers have integrated backwards in the food supply chain by setting up distribution centres and by selecting fewer suppliers. The food processing industry, wholesalers, may be concentrated as well. However, in general, fruit and vegetables processing is less concentrated. Policy-makers and industry representatives are increasingly worried that food retailers will use their size to set consumer prices above competitive levels and supplier prices below competitive levels (Murphy, 2006). Market power abuse may increase the wedge between producer and consumer prices and lead to a fall in consumer demand and production.

Environmental concerns

The horticulture sector is concerned about global warming and the need to reduce carbon dioxide (CO_2) emissions. Both governments and food retailers have put more stringent requirements on horticultural production. EU and national governments have introduced new regulations and directives, notably with respect to greenhouse gases (GHG) and renewable energy sources. Food retailers have laid down standards such as GLOBALGAP.

Based on agreements reached in Kyoto and the EU, the European Commission has an EU energy policy that seeks a unilateral 30 percent reduction of GHG emissions by 2020 (CEC, 2009). As part of the EU climate policy, the EU Emission Trading System (EU ETS) was established. The EU ETS is a cap-and-trade system: the cap guarantees the necessary emission reductions, while trading in allowances ensures that the least-cost abatement options are realized. Under the EU ETS, large emitters of CO_2 within the EU must monitor and annually report their CO_2 emissions. Each Member State has its own national registry containing accounts which will hold the allowances traded in the EU ETS. These registries are linked with the European Commission Community transaction log, which record and check every transaction. The EU ETS applies to a limited number of (large) glasshouse horticulture firms.

The EU CAP stimulates the production of renewable energy, and focuses on environmental standards such as biodiversity, nutrients, pesticides, water management and climate change. Environmental concerns have received more attention in the CAP. With cross-compliance in the current Single Payment Scheme, environmental objectives have attracted more attention. Both the CAP and CMO for fruit and vegetables embrace a cross compliance mechanism. Cross-compliance includes statutory management requirements (e.g. standards in the field of environment, food safety and animal and plant health) and good agricultural and environmental conditions (e.g. standards related to soil protection, maintenance of soil organic matter and structure, and water management). Under the WTO, SPS measures are imposed to protect plant health against plant pests, to facilitate more sustainable production, and to monitor the sale and use of pesticides.

EU regulations and directives to diffuse water pollution are the EU's Nitrate Directive and the Water Framework Directive. The Nitrate Directive aims to reduce water pollution from nitrates from agricultural sources, and to prevent further pollution. Under the Nitrate Directive, EU Member States must monitor water quality, establish measures of good agricultural practice, as well as measures to limit the application of any nitrogenous fertilisers (Brouwer and Silvis, 2010). The Water Framework Directive (WFD) aims that each Member State prevents and reduces pollution, promotes sustainable water use, protects the aquatic environment and mitigates the effects of floods and droughts (Brouwer and Silvis, 2010).

In addition to EU regulations, at the firm level, several private standards exist such as GLOBALGAP and the British Retail Consortium (BRC) Standards (Fulponi, 2007). The GLOBALGAP standard is designed to maintain consumer confidence in food quality and food safety. Other important goals are to minimize detrimental environmental impacts of farming operations, optimize the use of inputs and to ensure a responsible approach to worker health and safety. The BRC standards are designed to assess retail suppliers.

2.3 Review PE models

This section reviews how the impact of the three main issues on production and trade in horticulture (i.e. trade regulations, concentration within the chain, and environmental issues) are currently modelled in PE models. To identify windows for improvement, horticultural PE models are compared with agricultural PE models. A PE analysis is defined as an analysis that analyses how demand and supply in each market determine the equilibrium price and quantity in that market, independently of other markets (Salvatore, 1991). A PE model describes the market as a sum of individual demand and supply functions, a set of aggregate behaviour of both consumers and producers, and includes a set of identities which model the relationships between activities (Conforti, 2001). In a PE model, assumptions refer to the competitive nature of the market, the homogeneity of products, bilateral trade versus pooled trade relations, and static versus dynamic demand and supply relations. Bilateral relations are a set of interactions between each buyer and seller of the commodity. A comparative PE model can be either static or dynamic. Comparative static models compare two different outcomes (before and after a change), while a dynamic PE model studies the changes over time, which shows the long-term impacts of various policy measures. Comparative static models give more detailed outcomes of the impacts in the short term.

Trade regulations

Twenty-one PE models were found to consider trade regulations (Table 2.1). Ten PE models focused on products in the horticultural sector and the other eleven PE models focused on the agricultural sector. Parameters and impacts of trade measures for fruit and vegetables, such as entry prices and tariff quotas, are product-specific. For this reason, most analyses of trade policies for fruit and vegetables refer to one product. The choice for a single product model is legitimate, given the fact that trade policies are product-specific. However, product-specific models do not account for substitution or complementarity between products as a result of e.g. tariff reductions. This is an aspect which is taken into account in multi-product models. The agricultural PE models reviewed in this study, deal with multiple products. However, only four out of ten horticultural PE models can be characterised as multi-product models (Málaga *et al.*, 2001; Kavallari and Schmitz, 2007; Agrosynergie, 2008; Bunte and Kuiper, 2008). Bananas and tomatoes are the products that were most frequently considered in horticultural PE models. These products are characterised by a high consumer demand and are subject to specific trade regulations (i.e. former CMO for bananas and US-Mexico trade (NAFTA)).

EU trade policy affects imports and exports of all its Member States, which may influence the comparative advantage of the individual countries. For this reason, analyses of EU trade policies should include the EU as region of scope and differentiate for each Member State. All reviewed horticultural PE models dealt with a multi-country specification, whereas most of the agricultural PE models had a limited country range. Only two of the eleven agricultural PE models included a multi-country specification (Chantreuil *et al.*, 2005; von Ledebur *et al.*, 2005). Multi-country PE models allow for a more detailed representation of trade by including bilateral trade relations. According to Anania (2001), bilateral relations improve the realism, accuracy and detail of trade policy. Five horticultural

Table 2.1 Reviewed partial equilibrium (PE) models analysing trade regulations

Product[1]	Modelling issue	Assumption[2]				Scope of region[3]	Source
Horticultural sector							
Bananas	Quotas and tariff levels (old/new banana regime)	ni	C	B		EU25, ACP, L-America, ROW	(Guyomard and Le Mouël, 2003)
Tomatoes	TRQs, MFN, entry prices, tariff reduction	I	C	B		EU, Morocco, ROW	(Garcia-Alvarez-Coque *et al.*, 2009)
Bananas	Tariff reduction	I	C	B		Twenty regions; e.g. EU, ACP	(Vanzetti *et al.*, 2005)
Processed tomato	Tariff reduction & EU domestic support	I	ni	B		EU, US and ROW	(Rickard and Sumner, 2006, 2008)
Fresh tomatoes	Tariff Reduction	ni			E	US and Mexico	(Padilla-Bernal *et al.*, 2001)
Bananas	EU enlargement, different exchange rate (WTO)	H	ni	B		EU27, USA, ACP, ROW	(Anania, 2006)
Tomato, cucumber pepper, squad onion	Trade liberalization: change in exchange rates	H	D		E	US and Mexico	(Málaga *et al.*, 2001)
Grape, cucumber, tomato, clementine	CMO (EPS)	H	C			EU 25	(Agrosynergie, 2008)
Floriculture	VAT	I	C			EU 25	(Bunte and Kuiper, 2008)

Agricultural sector							
	CAP reform (quota, SPS, reduction payments)	H	D		E	Netherlands	(Tabeau and Leeuwen, 2008)
	CAP reform (intervention price, reduction payment)	H	D		E	EU15	(Chantreuil *et al.*, 2005)
	CAP Reform	ni	D		E	Spain	(Casado and Gracia, 2005)
Arable crop	CAP (SPS)	ni	D		E	Spain	(Gracia *et al.*, 2008)
Wheat, barley, sunflower, maize	CAP (SPS)	H	D		E	Romania	(Gravilescu *et al.*, 2006)
16 commodities (e.g fruit, wheat)	EU enlargement, unilateral + multilateral liberalization	H	C			EU Member States	(Kavallari and Schmitz, 2007)
Beef, dairy	WTO restrictions	H	D			Ireland	(Binfield *et al.*, 2009)
8 products (e.g fruit, meat, dairy)	EU enlargement, participation CAP.	H	C		E	Malta	(Mizzi, 1993)
Sugar	Free access tariff reduction, EU liberalizations	H	D	B	E	EU 27 + >100 regions	(Nolte, 2008)
Feed, livestock	EU-Accession	H	C			Macedonia	(Pelling, 2007)
Dairy, meat	Tariff reduction and WTO	H	D	B		Switzerland	(Ali, 2008)
Beef, dairy	Intervention price	H	C		E	EU	(von Ledebur *et al.*, 2005)

[1] If other than agricultural sector

[2] H=homogeneous goods; I=imperfect substitutes; D=dynamic model; C=comparative static model; E=econometric model; B= bilateral relations; ni =no information

[3] ROW= rest of the world; ACP = Africa, Caribbean and Pacific regions

2

PE models considered bilateral relations (Guyomard and Le Mouël, 2003; Vanzetti *et al.*, 2005; Anania, 2006; Rickard and Sumner, 2006; Garcia-Alvarez-Coque *et al.*, 2009), whereas only two agricultural PE models included these relations (Ali, 2008; Nolte, 2008).

Models distinguishing bilateral trade may recognize product heterogeneity, products as imperfect substitutes, with respect to the country-of-origin. Of the five horticultural PE models which included bilateral trade relations, four horticultural PE models specified a product from different countries as imperfect substitutes (Vanzetti *et al.*, 2005; Rickard and Sumner, 2006; Bunte and Kuiper, 2008; Garcia-Alvarez-Coque *et al.*, 2009). Using the assumption of imperfect substitutes, a country can act both as an importer and exporter of products. This approach yields more detailed and realistic results rather than assuming homogeneity of products. The appropriateness of the assumption of static rather than dynamic modelling, depends on the time horizon of the policy. Dynamic modelling was applied by only one horticultural PE model (Málaga *et al.*, 2001). This is different from the agricultural PE models, where eight of the eleven models considered dynamics. However, the modelling issues (i.e. CAP Reform, liberalization and access) of these models may have asked for results in the long term.

PE models can use econometrically estimated or calibrated parameters. Econometrically estimated parameters are based on observations, while calibrated parameters are based on benchmark data and theory. Econometric estimation of key behavioural parameters is preferred because it uses a larger amount of data. Given the lack of horticultural data (and over time), this is generally not feasible. From the ten horticultural PE models, two models used econometrically estimated parameters (Padilla-Bernal and Thilmany, 2000; Málaga *et al.*, 2001), whereas seven out of the eleven agricultural PE models included econometrically estimated parameters (Mizzi, 1993; Chantreuil *et al.*, 2005; von Ledebur *et al.*, 2005; Gravilescu *et al.*, 2006; Gracia *et al.*, 2008; Nolte, 2008; Tabeau and Leeuwen, 2008).

In summary, current horticultural PE models are well developed in modelling policy specific details of trade regulations such as tariffs, quotas, tariff-quotas and entry prices, as well as the enlargement of the EU. Shortcomings of the current horticultural PE models are the multi-product range, commodities as imperfect substitutes and the use of bilateral trade flows and econometric parameters.

Concentration among producers, retailers and discount chains

In this review, nine PE models were found to consider concentration among producers and especially among food retailers (Table 2.2). Four PE models focused on products in the horticultural sector and the other five PE models focused on the agricultural sector. Agricultural commodities are traded worldwide, but due to differences in consumer preferences with respect to taste, packaging and consumer characteristics in terms of culture and language, final consumer products differ between national markets. Most current PE analyses rightly involve only one country, whereas only two agricultural PE models include a multi-country specification (Sckokai and Soregaroli, 2008; Song *et al.*, 2009).

When assessing retail market power, it is important to decide upon the number of products to include in the analysis. Retailers do not only sell tomatoes or fruit, but sell a wide variety of groceries. Analyses focusing on one or a limited number of products may be misleading. The literature provided both single-product (Just and Chern, 1980; Melnick and Shalit, 1985; Réquillart *et al.*, 2008; Sckokai and Soregaroli, 2008; Song *et al.*, 2009) and multi-product specifications (Gohin and Guyomard, 2000; Sexton and Zhang, 2001; Moro *et al.*, 2002).

Related to product choice is the question on how to deal with product differentiation. Retail pricing takes differences in consumer willingness to pay (and price elasticities) into account when deciding upon prices and on which varieties to obtain retail margins. One horticultural PE model dealt with a product as an imperfect substitute (Réquillart *et al.*, 2008). Two of the agricultural PE models considered products as homogeneous and as imperfect substitutes (Moro *et al.*, 2002; Sckokai and Soregaroli, 2008).

When analysing the effect of market power a comparative static model is more appropriate (Réquillart *et al.*, 2008). One is interested in the difference between the situation with and without market power. To estimate structural price relations, one may take into account price dynamics in their model, like Melnick and Shalit (1985), Sckokai and Soregaroli (2008) and Song *et al.* (2009).

In summary, current horticultural PE models are relatively well-suited for modelling concentration at the retail level. However, in the horticulture sector competition not only occurs at the retail level, but also at wholesale level. The latter is not analysed yet in any current horticulture PE model. Other shortcomings in these current horticulture PE models are the multi-region and multi-product specifications.

Environmental concerns

Although energy use and its related CO_2 emissions are among the most important environmental concerns related to horticulture, only one current European (Dutch) PE model for horticulture dealt with energy (Bunte and Galen, 2005) (Table 2.3). The other two horticultural PE models dealt with fertilizer use in the US (Roosen, 2001) and pest invasion in the Netherlands (Surkov *et al.*, 2009). They do not analyse major environmental issues such as emissions of GHGs and the more environmentally friendly use of pesticides, water and nutrients. On the other hand, there were several agricultural PE models considering environmental

Table 2.2 PE reviewed models dealing with different market structures

Product	Level[1]	Modelling issue	Assumption[2]			Scope of region	Source
Horticultural sector							
Fresh tomato	R	Oligopoly / oligopsony	I	C		France	(Réquillart *et al.*, 2008)
Fresh tomato	P/R	Monopoly and monopsony	H	D	E	Israel	(Melnick and Shalit, 1985)
Processed tomato	P	Monopsony and oligopsony	H		E	California	(Just and Chern, 1980)
Banana	R	Oligopoly and perfect competition	H		E	Turkey	(Hatirli *et al.*, 2003)
Agricultural sector							
Cereal	R	Monopoly, perfect competition	H/I	D	E	fictive 2 countries	(Sckokai and Soregaroli, 2008)
Beef, dairy	P/R	Oligopsony slaughtering firms, retailer oligopoly	H/I*			Italy	(Moro *et al.*, 2002)
Food industry	F/R	retailer oligopoly, manufacturer oligopsony	H			fictive single country	(Sexton and Zhang, 2001)
Soybean	F/R	Monopsony / oligopoly	H	D		US & China	(Song *et al.*, 2009)
Dairy, meat, other	R/W	Oligopoly / oligopsony	H		E	France	(Gohin and Guyomard, 2000)

[1] P= producers/processing level; W=wholesale level; R= retail level

[2] H=homogeneous goods; I=imperfect substitutes; D= dynamic model; C= comparative static model; E= econometric model; H/I homogeneous assumption beef, imperfect substitutes dairy; * homogeneous assumption domestic firms, imperfect substitute's trade

2

Table 2.3 PE reviewed models dealing with sustainability and environment

Product[1]	Modelling issue	Assumption[2]			Scope of region[3]	Source
Horticultural sector						
Fruit, vegetables, ornamentals	Energy prices	H	C	B	EU-25, Morocco, Turkey, ROW	(Bunte and Galen, 2005)
Apples	Fertilizer use	H	D		US	(Roosen, 2001)
Chrysan-themum	Pest damage	H	D	ni	Netherlands, ROW	(Surkov *et al.*, 2009)
Agricultural sector						
	Biomass subsidy, electricity & carbon tax	H	C		Poland	(Ignaciuk *et al.*, 2006)
Grains, oilseeds, live-stock, dairy	Biofuels	H	D		EU	(Binfield *et al.*, 2008)
Potato	Quarantine diseases	H	C	P	EU, ROW	(Breukers *et al.*, 2008)
	Energy prices	H	C	P	EU27	(Kempen and Kraenzlein, 2008)
Dairy	GHG	I	C	B	18 countries; e.g Australia, EU, US, New Zealand	(Saunders and Wreford, 2005)
Food, bioenergy	Biofuels	I	C	B	EU, Saharan Africa, ROW	(Schneider *et al.*, 2008)
	GHG	H	D		Ireland	(Donnelan *et al.*, 2009)
	Biofuels	H	D		US	(Hayes *et al.*, 2009)
	Biofuels	H	D	P	13 regions e.g. US, EU, Brazil, ROW	(Peters *et al.*, 2009)

1 If other than agricultural sector
2 H= homogeneous goods; I= imperfect substitutes; D= dynamic model; C= comparative static model; B= bilateral market; P= pooled market; ni = no information
3 ROW= Rest of the World (aggregated group)

issues, such as renewable energy sources and greenhouse gas emissions. However, in the horticultural sector, biofuels are used for heating greenhouses. In the agricultural sector, biofuel is mainly used as an economic alternative to other energy sources. As a consequence, agricultural PE models focused mainly on differences in subsidies and prices, and transport usage. Other environmental effects such as the use of water and pesticides are not modelled yet in the current PE models.

Changes in the prices of energy and CO_2 not only affect the international competitiveness of the Dutch greenhouse industry with respect to countries outside Europe, but also with respect to the southern Member States (e.g. Spain). A shift of production to southern Europe and developing countries outside Europe could reduce global CO_2 emissions and increase the efficiency of production (Bunte and Dijkxhoorn, 2009). As a result, energy policy will promote Mediterranean horticultural production to the detriment of North-European products. Due to the fact that environmental policy may have an impact on the comparative advantage of countries with respect to horticultural production, PE models should consider a multi-country specification. Two horticultural PE models (Bunte and Galen, 2005; Surkov *et al.*, 2009) include a multi-country range but focus in their analysis on one country (i.e. Netherlands). The role and importance of the geographical region is further underrepresented in the current horticultural PE models (Roosen, 2001). Five agricultural PE models analysed different countries. Two of these (Saunders and Wreford, 2005; Schneider *et al.*, 2008)2008 considered bilateral relations, whereas the other three models (Breukers *et al.*, 2008; Kempen and Kraenzlein, 2008; Peters *et al.*, 2009) considered the relations as a pooled group. One of the horticultural PE models dealt with bilateral relations (Bunte and Galen, 2005), in line with their regional scope.

An important characteristic of the Dutch greenhouse sector is the fact that firms are both energy producers and consumers. This characteristic calls for modelling products of countries as imperfect substitutes rather than assuming homogeneity. From the current PE models, two agricultural PE models (Saunders and Wreford, 2005; Schneider *et al.*, 2008)2008 considered products as imperfect substitutes.

2.4 Conclusion and Discussion

This chapter reviewed existing horticultural PE models which analyse trade regulations, concentration in the chain and environmental concerns. Our review provided insight in their strengths and weaknesses and identified gaps in currently available models requiring further research. It appeared that horticultural PE models which focus on trade regulations are better represented than models focusing on market concentration and environmental concerns.

Trade regulations

Trade regulations and the enlargement of the EU were more widely considered by the horticultural PE models rather than by agricultural PE models. A PE model should be sensitive to changes in policies at the European level and therefore include multiple ranges of countries. The current PE models satisfy this requirement. However, most of the currently available horticultural PE models are product-specific and do not pay attention to substitution or complementarity with other horticultural or agricultural products. Doing so is important, both from welfare, economic and policy perspectives. The analysis of EU enlargement and trade regulations also depends on the assumptions of commodities as imperfect substitutes, the use of econometric estimations and the use of bilateral trade flows. Econometric estimation of parameters is underrepresented in currently available horticultural PE models, while this improves the realism, accuracy and detail of the representation of a trade policy. Given the prospect of upcoming trade negotiations, modelling bilateral flows should be common to incorporate bilateral measures and tariff quotas. Moreover, a PE model which analyses trade regulations should account for seasonality of supply and demand. Nowadays, consumers' demand for year-round fresh fruit and vegetables is increasing. This means that horticultural products may be traded all year-round, resulting in differences in the input demand and output supply throughout the year.

Concentration within the chain

In a market-oriented environment, such as the Dutch greenhouse sector, any intervention at firm level will be transmitted to final consumers, and a complete picture of a policy change, therefore, calls for modelling more levels of the chain. Likewise, changes in consumer demand and retailers' buying and marketing policies impact production and trade in horticulture. In principle, both aspects can be dealt with in a one-product, one-country model. A problem with a one-product model analysing market concentration is that possible cross-subsidies are neglected. Both retailers and consumers are interested in a variety of products. A one-country model does not take into account possible product substitution and competition between countries. Current horticultural PE models do not take into account a multi-country and a multi-product criterion. Another major shortcoming in the current PE models is that they estimate the gap between prices and marginal costs, but do not relate the profit margin to such explanatory variables as market concentration. A specific issue in modelling imperfections in supply chain pricing, is the occurrence of asymmetric price adjustment. Asymmetric adjustment refers to the fact that increases in purchasing prices are transmitted more fully and quickly than decreases. Future PE models may incorporate this prospect.

Environmental concerns

Incorporating environmental issues is a white spot in horticultural PE models. These models may play a role in meeting future demand for quantitative impact assessments. In Northern Europe, and more specifically the Dutch greenhouse industry, environmental (energy) policies impact on horticulture's competitiveness. Southern Europe is likely to face more stringent demands with respect to the use of water and pesticides. To reflect the differential impacts of environmental policies, future horticulture PE models should be region-specific. Incorporating environmental issues in PE models requires a re-specification of supply and demand relations through: (1) a multi-regional range; (2) the use of bilateral trade flows; and (3) the consideration of goods as imperfect substitutes. For example, trade in CO_2 emission rights following from the implementation of the ETS requires a specification of bilateral trade flows. Allowing for imperfect substitution is important where countries supply and consume energy.

In summary, modelling environmental concerns received the least attention in currently available horticultural PE models (Table 2.4) and yet, these concerns are subject today to new regulations and public demand. Concentration within the chain is only weakly reflected in current PE models. Accounting for market concentration is important as the perceived increasing market power of food retailers is a major concern for actors in the chain and public bodies. Trade regulations are well represented in the current horticultural PE models, as the horticultural sector has been subject to trade regulations for more than fifteen years.

As a result, future horticultural PE models should be developed in such a way that they can be used for modelling market changes for multiple horticultural commodities, provided that the data are adapted to the particular set of commodities. An improved model of the impact of trade policy changes and EU enlargement, concentration within the chain and environmental concerns, calls for the development of multi-product models in multiple countries that consider products as imperfect substitutes and uses bilateral trade flows and econometric estimations. A multi-country multi-product PE model is a PE model extended vertically or horizontally to include other markets. Multi-market models offer more accurate ex ante impact analysis than single-market models by including possibly indirect effects such as substitution and complementarity between commodities.

Future PE models would benefit from explicitly addressing seasonality. However, a limitation in addressing the discussed issues in future horticultural PE model is the availability of quantitative data from actors throughout the whole chain.

Table 2.4 Current state and desirable future specifications of horticultural PE models

	Trade regulations		Market concentration		Environmental issues	
Specifications	**Current[1]**	**Future[2]**	**Current**	**Future**	**Current**	**Future**
Multi product	+/-	P1[3]	-	P1	+/-	X
Imperfect substitutes	+/-	P3	+/-	P3	-	P3
Dynamics	+/-	ni	+/-	ni	+/-	ni
Bilateral trade flows	+	x	np	ni	-	P2
Econometric estimation	+/-	P2	+	x	ni	X
Multi country	+	x	-	P2	+/-	P1
More levels of the chain			+/-	x		

[1] The current state of the specification: - = not included in current horticultural PE models; +/- = underrepresented in current horticultural PE models; + = represented in majority of current horticultural PE models; np= not present in current horticultural PE models

[2] The desirable future specifications: x= desirable to include in future horticultural PE model; ni = no information if this assumption is more desirable in future horticultural PE models

[3] Priority specifications to include in future horticultural PE models; P1 = first priority; P2= second priority; P3 = third priority

References

Agrosynergie. 2008. Evaluation of the system of entry prices and export refunds in the fruit and vegetables sector. Available at: "http://ec.europa.eu/agriculture/eval/reports/fruitveg/exsum_en.pdf" (last accessed December 1 2009).

Ali, F. 2008. Reform and the WTO: Potential Impacts on Swiss agriculture. Paper presented at: 107th EAAE Seminar, Seville, Spain, January 29 - February 1.

Anania, G. 2001. Modeling Agricultural Trade Liberalization. A Review. Paper presented at: Annual meeting AAEA, Chicago, U.S., August 5-8.

Anania, G. 2006. The 2005 WTO arbitration and the new EU import regime for bananas: a cut too far? *European Review of Agricultural Economics* 33: 449-484.

Anders, S. 2005. Measuring market power in German food retailing: Regional Evidence Institution of Agricultural policy and market research.

Balkhausen, O., Banse, M. and Grethe, H. 2008. Modelling CAP Decoupling in the EU: A Comparison of Selected Simulation Models and Results. *Journal of Agricultural Economics* 59: 57-71.

Binfield, J., Westhoff, P. and Le Cadre, E. 2008. Incorporating biofuels into a partial equilibrium model of the EU agricultural sector. . Paper presented at: 107th EAAE seminar, Seville, Spain, January 29-February 1st.

Binfield, J.C.R., Donnelan, T., Hanrahan, K. and Westhoff, P. 2009. WTO Doha Round: impact of an Agreement on Agriculture and tthe Importance of Sensitive Product Status. . Paper presented at: 83rd annual conference of the AES, Dublin, Ireland, 30th March - April 1st.

Bogers, R.P. 2007. The future of horticultural science and education: an European perspective *Chronica Horticulturae* 47: 4-6.

Breukers, A., Mourits, M., Werf, W.v.d. and Lansink, A.O. 2008. Costs and benefits of controlling quarantine diseases: a bio-economic modeling approach. *Agricultural Economics* 38: 137-149.

Brouwer, F. and Silvis, H., 2010. "Rural areas and the environment", in A. Oskam, G. Meester and H. Silvis (eds.), *EU Policy for Agriculture, Food and Rural Areas.* (Wageningen: Wageningen Academic Publishers, 2010, 337-349).

Bunte, F. 2009. Prijsvorming glastuinbouw. Nota 09-02.Den Haag: Agricultural Economics Research Insitute (LEI).

Bunte, F. and Dijkxhoorn, Y. 2009. *CO2-emissiehandel in 2020 : betekenis voor de Nederlandse glastuinbouw*. Den Haag: LEI Wageningen UR.

Bunte, F. and Galen, M., van. 2005. The effects of energy price increases on Dutch horticulture. Paper presented at: 11th EAAE Congress, Copenhagen, Denmark, August 24 - 27.

Bunte, F. and Kuiper, E. 2008. Promoting Floriculture Using VAT Regulation. *European Journal of Horticultural Science* 73: 248-253.

Casado, J.M. and Gracia, A., 2005. "An Assessment of Luxembourg agreement on the Spanish Agricultural sector: An econometric model", in F. Arfini (ed.), *Modelling Agricultural Policies: state of the art and new challenges*: Monte Universitá Parma, 2005, 496-511).

CEC. 2007. Council Regulation (EC) No 1182/2007 of 26 September 2007 laying down specific rules as regards the fruit and vegetable sector, amending Directives 2001/112/EC and 2001/113/EC and Regulations (EEC) No 827/68, (EC) No 2200/96, (EC) No 2201/96, (EC) No 2826/2000, (EC) No 1782/2003 and (EC) No 318/2006 and repealing Regulation (EC) No 2202/96. L 276. *Official Journal of the European Union* 50:1-30.

CEC. 2009. Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020. L 140. *Official Journal of European Union* 52:136-148.

Chantreuil, F., Hanrahan, K. and Levert, F., 2005. "The Luxembour agreement reform of the CAP: An analysis using the AGMEMOD composite model", in F. Arfini (ed.), *Modelling Agricultural Policies: state of the art and new challenges* (Parma: Monte Universitá Parma, 2005, 632-652).

Conforti, P., 2001. "The Common Agricultural Policy in main Partial Equilibrium Models", in G. Anania (ed.), *Valutare gli effetti della politica agricola comune : lo stato dell'arte dei modelli per l'analisi quantitativa degli effetti delle politiche agricole dell'Unione Europea*, 2001, 11-59).

Donnelan, T., Gillespie, P. and Hanrahan, K. 2009. Impact of greenhouse gas abatement targets on agricultural activity. Paper presented at: 83rd annual AES conference, Dublin, Ireland, 30th March - April 1st.

Fulponi, L., 2007. "The globalization of private standards and the agri-food system", in J.F.M. Swinnen (ed.), *Global supply chain, standards and the poor: How the globalization of food systems and standards affects rural development and poverty* (Wallingford: CABI, 2007, 5-18).

Garcia-Alvarez-Coque, J.M., Martinez-Gomez, V. and Villanueva, M. 2009. A trade model to evaluate the impact of trade liberalisation on EU tomato imports. *Spanish Journal of Agricultural Research* 7: 235-247.

Gohin, A. and Guyomard, H. 2000. Measuring Market Power for Food Retail Activities: French Evidence. *Journal of Agricultural Economics* 51: 181-195.

Gracia, A., De Magistris, T. and Casado, J.M. 2008. The effect of the new single farm payment in irrigated agriculture: the case of Spain. Paper presented at: 107th EAAE seminar, Seville, Spain, January 29th - February 1st.

Gravilescu, C., Gavrilescu, D. and Kevorcian, C. 2006. The accession of Romania to the European Union - Scenario analysis for key agricultural crop markets using AGMEMOD model. Paper presented at: IAS Conference, Gold Coast, Australia, August 12th-18th.

Guyomard, H. and Le Mouël, C. 2003. The new banana import regime in the European Union. *Journal of International Law and Trade Policy* 4: 143-161.

Hatirli, S.E., Jones, E. and Aktas, A.R. 2003. Measuring the market power of the banana import market in Turkey. *Turkish journal of agriculture & forestry* 27: 367-373.

Hayes, D.J., Babcock, B.A., Fabiosa, J.F., Tokgoz, S., Elobeid, A.E., Yu, T.-H., Dong, F., Hart, C.E., Chavez, E.C., Pan, S., Carriquiry, M. and Dumortier, J. 2009. Biofuels: Potential Production Capacity, Effects on Grain and Livestock Sectors, and Implications for Food Prices and Consumers. *Journal of Agricultural and Applied Economics* 41: 465-491.

Huige, R., Lapperre, R. and Stanton, G., 2010. "The WTO context", in A. Oskam, G. Meester and H. Silvis (eds.), *EU Policy for Agriculture, Food and Rural Areas* (Wageningen: Wageningen Academic Publishers, 2010, 89-102).

Ignaciuk, A., Vöhringer, F., Ruijs, A. and van Ierland, E.C. 2006. Competition between biomass and food production in the presence of energy policies: a partial equilibrium analysis. *Energy Policy* 34: 1127-1138.

Just, R.E. and Chern, W.S. 1980. Tomatoes, Technology, and Oligopsony. *The Bell Journal of Economics* 11: 584-602.

Kavallari, A. and Schmitz, P.M. 2007. An empirical assessment of agricultural trade policies in the Mediterranean basin - an regional effect on the EU member stages. Paper presented at: 103rd EAAE seminar, Barcelona, Spain, April 23th- 25th.

Kempen, M. and Kraenzlein, T. 2008. Energy use in agriculture: a modeling approach to evaluate energy reduction policies. Paper presented at: 107th EAAE seminar, Seville, Spain, January 29th - February 1st.

Málaga, J.E., Williams, G.W. and Fuller, S.W. 2001. US–Mexico fresh vegetable trade: the effects of trade liberalization and economic growth. *Agricultural Economics* 26: 45-55.

Melnick, R. and Shalit, H. 1985. Estimating the Market for Tomatoes. *American Journal of Agricultural Economics* 67: 573-582.

Mizzi, L. 1993. A static partial equilibrium analysis of Malta's Entry in the EC: the case of agriculture. Options Méditerranéenes.Malta: Food, Agriculture, Fisheries and the Environment.

Moro, D., Sckokai, P. and Soregaroli, C. 2002. A Partial Equilibrium Model of the Beef and Dairy Sector in Italy Under Imperfect Competition. Paper presented at: EAAE International Congress, Zaragoza, Spain, August 28-31.

Murphy, S. 2006. Concentrated Market Power and Agricultural Trade. Discussion paper 1, Ecofair Trade Dialogue.

Nolte, S. 2008. The future of world sugar market - a spatial price equilibrium analysis. Paper presented at: 107th EAAE seminar Seville, Spain, January 29th- February 1st.

O'Toole, R. and Matthews, A. 2002. The IMAGE CGE Model: Understanding the Model Structure, Code and Solution Methods. Trinity Economics Papers.

Padilla-Bernal, L. and Thilmany, D. 2000. Mexican - U.S Fresh tomato trade: An analysis of volume, prices and transaction costs Paper presented at: WAEA meeting, Vancouver, Canada,

Padilla-Bernal, L., Thilmany, D. and Loureiro, M. 2001. Tradability and market equilibrium for US-Mexico fresh tomatoes. *Journal of Agricultural and Resource Economics* 26: 567-567.

Pelling, E. 2007. *Macedonia at the doorstep of the European Union*, SLU Uppsala).

Pérez Dominguez, I., Gay, S.H. and M'barek, R. 2008. An integrated model platform for the economic assessment of agricultural policies in the European Union. *Agrarwirtschaft* 57: 379-386.

Peters, M.M., Somwaru, A., Hansen, J., Seeley, R. and Dirkse, S. 2009. Modeling biofuels expansion in changing global environment. Paper presented at: IAS Conference, Beijing, China, August 16-22.

Réquillart, V., Simioni, M. and Varela Irimia, X. 2008. Imperfect competition in the fresh tomato industry. Paper presented at: EAAE International Congress, Ghent, Belgium, August 26 - 29.

Rickard, B.J. and Sumner, D.A. 2006. EU support would benefit California tomato growers and processors. *California Agriculture* 60: 207-210.

Rickard, B.J. and Sumner, D.A. 2008. Domestic Support and Border Measures for Processed Horticultural Products. *American Journal of Agricultural Economics* 90: 55-68.

Roosen, J. 2001. Regulation in Quality differentiated markets: pesticide cancellations in U.S. Apple Production. *Journal of Agricultural and Applied Economics* 33: 117-133.

Salvatore, D. 1991. *Microeconomics*. New York: Harper Collins.

Saunders, C. and Wreford, A. 2005. Agricultural Trade liberalization and greenhouse gas emissions: modeling the linkages using a partial equilibrium trade model. *Agricultural and Resource Economics Review* 34: 32-41.

Schneider, U.A., Llull, C. and Havlik, P. 2008. Bioenergy and Food security Modeling income effects in a partial equilibrium model. Paper presented at: 12th EAAE congress, Gent, Belgium, August 26-29.

Sckokai, P. and Soregaroli, C. 2008. Imperfect Competition in Internation Cereal Markets. Paper presented at: XLV Congress SIDEA, Portici, Italy, September 25-27.

Sexton, R.J. and Lavoie, N. "Food processing and distribution: An industrial organization approach", in B.L. Gardner and G.C. Rausser (eds.), *Handbook of Agricultural Economics*: Elsevier, 2001, 863-932).

Sexton, R.J. and Zhang, M. 2001. An assessment of the impact of food industry market power on U.S. consumers. *Agribusiness* 17: 59-79.

Song, B., Marchant, M.A., Reed, M.R. and Xu, S. 2009. Competitive Analysis and Market Power of China's Soybean Import Market. *International Food and Agribusiness Management Review* 12: 21-42.

Surkov, I.V., Lansink, A.G.J.M.O. and van der Werf, W. 2009. The optimal amount and allocation of sampling effort for plant health inspection. *European Review of Agricultural Economics* 36: 295-320.

Tabeau, A. and Leeuwen, M., van. 2008. Importance of CAP reforms for the Dutch Agricultural Sector in 2000-2020. Paper presented at: 109th EAAE Seminar, Viterbo, Italy, November 20-21.

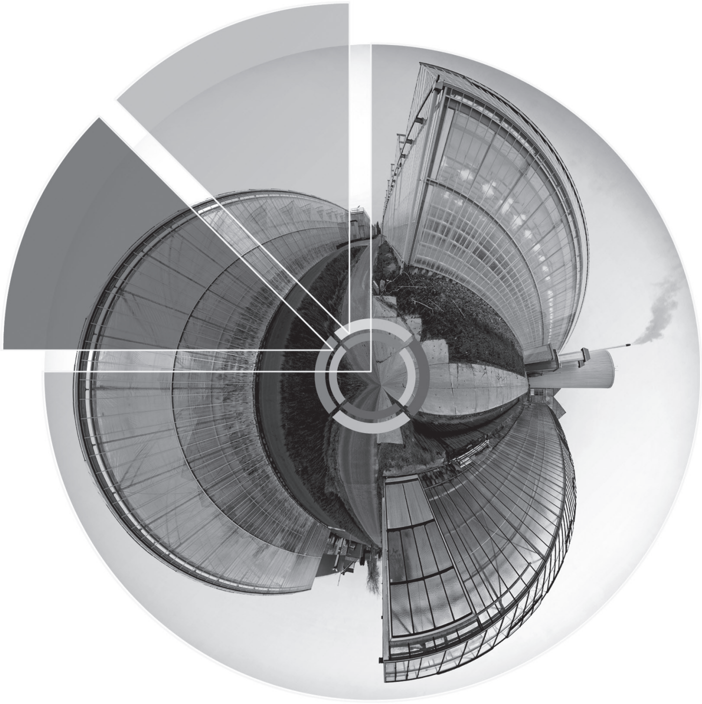
van Tongeren, F., van Meijl, H. and Surry, Y. 2001. Global models applied to agricultural and trade policies: a review and assessment. *Agricultural Economics* 26: 149-172.

Vanzetti, D., De Córdoba, S.F. and Chau, V. 2005. Banana split: How EU policies divide global producers. Trade Analysis Branch Division on International Trade in Goods and Services and Commodities. UNCCTAD United Nations.

von Ledebur, O., Salamon, O. and Weber, G. 2005. Who is telling the truth? : Synthetic uniformly structured or econometric country specific models - a model comparison based on the Luxembourg Agreement. Paper presented at: 89th EAAE Seminar, Parma, Italy, February 3-5.

Wijnands, J.H.M., van der Meulen, B.M.J. and Poppe, K.J. 2007. *Competitiveness of the European food industry : an economic and legal assessment*. Luxembourg: Office for Official Publications of the European Communities.

Wu Huang, S. 2004. Global Trade Patterns in Fruits and Vegetables. Agriculture & Trade Report WRS-04-06.Washington D.C: U.S. Department of Agriculture (USDA).



3

Border closure modelling under imperfect competition: A partial equilibrium model of the Dutch tomato sector

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Abstract

This chapter simulates impacts of a reduction in domestic consumption due to health scare and a border closure in the export market of Dutch fresh tomatoes. A partial equilibrium model is developed and used to analyse the short-term impacts on supply, demand and prices at the producer, wholesale and retail stages in an imperfect competitive setting. The model takes into account international trade, market power at the retail level and seasonality effects. Our results suggest that border closure has higher significant impacts on all stages throughout the chain than health scare issues. If consumer and export demand declines simultaneously with the occurrence of a border closure, the impact on producer prices is more than three times the impact on retail prices in high season. When competition at the retail level increases, total welfare losses are higher. The net change in domestic total welfare is more negative in the high production season than in the low production season.

Keywords: Simulation model; International trade; Imperfect competition; Health scare; Border closure; Tomato sector

3.1 Introduction

Over the past decade, the greenhouse horticulture sector in the Netherlands has experienced a number of exogenous market shocks, such as health scare issues and border closures. The most recent health scare example in recent years was the Enterohemorrhagic Escherichia coli bacteria (EHEC) in Western Europe. In spring 2011, the Russian border was closed to imports of West European fresh vegetables. Fresh vegetables were suggested to be the source of infection, which also resulted in a health scare. To date, 39 deaths can be linked to EHEC contamination in Germany (van der Kolk, 2011). In the Netherlands, the EHEC announcement led to a fall in the consumption of greenhouse vegetables. The European Commission adopted a regulation with temporary measures focused on market intervention measures, and aimed at decreasing the market pressure so that producer prices could return to normal levels. Dutch producers were compensated by an intervention price for tomatoes which had to be destroyed. However, the EHEC outbreak and the border closure still caused a drop of approximately 5 percent in exports and Dutch wholesalers and producers suffered millions of euros of damage (Product Board Horticulture, 2011). Another example of a border closure to Dutch greenhouse products was in 2004. The Russian border did not open to trade in Dutch ornamentals (cut flowers and potted plants) and greenhouse fruit and vegetables after a shipment showed up with crop-eating insects. Russia is an important export country for Dutch ornamentals; hence the suspension of imports from Dutch ornamentals caused a 30 percent drop in prices and export losses of approximately 15 percent on a daily basis (Zweers, 2004).

Health scares have a short-term negative impact on consumption behaviour (Roosen *et al.*, 2003), and therefore affect international agricultural trade. In the light of the increasing globalization of trade and growth of greenhouse horticulture, health scares and simultaneous border closures may happen more frequently. Past literature focused on the effect of a health scare hazard or food safety concerns to human food consumption or prices. Most of the studies found little or no significant effect on the fresh produce consumption or on the elasticity of consumer demand (Brown, 1969; Henneberry *et al.*, 1999; Dahlgran and Fairchild, 2002; Piggott and Marsh, 2004). More recently Lloyd *et al.* (2001) and Serra (2011) looked at the impacts of a food scare on the price transmission and price volatility, respectively. The research of Lloyd *et al.* (2001) was motivated by public concern that the food scare crisis had differential effects on retailers and producers. For the case of the EHEC bacteria crisis and the consecutive Russian import ban in the Netherlands, the main losses in the Dutch horticulture greenhouse chain occurred at the producer and wholesale stages, while retail turnovers did not show significant changes compared to 2010 or previous years. In this regard, attention is drawn to possible market power at the retail level. Dutch agriculture is characterized by its high degree of short-term price changes. It has not been uncommon in recent years for the producer and wholesale prices of an agricultural product to fluctuate, while consumer prices hardly fluctuate (Sexton and Zhang, 2001; Vavra and Goodwin, 2005). Due to the increasing retail consolidation, retail firms face lower costs and higher profits. In general, it is thought that the consolidation enables retailers to exercise buying and selling market power (Kaditi, 2011). Imperfect competition may have an important role in influencing the outcomes of policy measures (Soregaroli *et al.*, 2011).

The recent drops in agricultural prices and changes in international supply and demand have raised questions about the effects of exogenous shocks at all stages of the agricultural food supply chain. Exogenous market shocks, such as border closures and health scares have significant impact on supply, demand and prices. To understand the supply and demand effects of exogenous shocks quantitative models have become a common tool for policy-makers. Many existing agricultural simulation models have focused on the impact of trade restrictions only (i.e. quota's and tariff reduction) on agricultural production. Economic impacts of trade shocks in the greenhouse sector have been analysed by Malaga et al. (2001), Bunte and Kuiper (2008), Rickard and Sumner (2008) and Garcia-Alvarez-Coque et al. (2010). None of them, however, focused on border closures specifically. Moreover, regarding the fresh vegetables sector, the models are mostly related to the United States, Mexico or the European Union as one region.

Verreth *et al.* (2011) conducted a review of the existing literature on partial equilibrium models in the horticulture sector. Models which incorporate trade regulations, increased market concentration or environmental concerns were reviewed. Trade regulations were considered rather widely, but border closures were not taken into account (Verreth *et al.*, 2011). Imperfect competition, or market power, has also been incorporated in several agricultural simulation models (Just and Chern, 1980; Melnick and Shalit, 1985; Hatirli *et al.*, 2003; Sexton *et al.*, 2007; Réquillart *et al.*, 2008). The existing partial equilibrium models that incorporate market concentration only take into account one or two stages of the chain, rather than multiple stages (Verreth *et al.*, 2011). Indeed, in a market-oriented environment, an exogenous shock is often transmitted to all downstream stages in the chain. Moreover, the use of econometrically estimated parameters and the consideration of seasonality of supply and demand were missing. Soregaroli *et al.* (2011) incorporated both trade flows and market structures, but modelled imperfect competition in the dairy sector.

Only few studies developed partial equilibrium simulation models that account for trade flows and different market structures in the chain (i.e. imperfect competition), whereas models targeting the Dutch greenhouse sector are absent

(Verreth *et al.*, 2011). Although health scares and border closures regularly occur and are expected to occur in the future, knowledge of the potential consequences of export restrictions (border closures) is limited. Better knowledge of the economic consequences of market shocks, such as changes in consumer and export demand due to health scare, simultaneous border closures, and taking into account market structure (i.e. market power), gives insight in the Dutch greenhouse sector and enables assessment of ex-ante measures.

Therefore, the aim of this chapter is to quantify the impacts of health scares and border closures on supply, demand and prices of a Dutch vegetable supply chain, namely tomatoes. To do so, a partial equilibrium model approach is used that simulates the short-term impacts of export market closures and changes in consumer demand due to health scare in different production seasons (low and high production seasons) for Dutch tomatoes. The model distinguishes the producer, wholesale, retail and consumer stages in an imperfectly competitive supply chain and links firm decision making to market results. Trade flows and seasonality are incorporated in the model. In addition, the implications of various combinations of market structures (i.e. perfect competition, oligopolistic market structure) on supply, demand, prices and total welfare are derived. This study contributes to the literature by providing an overview of the impact of border closure and market power on supply, demand and welfare. The analysis is done for the Dutch greenhouse tomato chain, because of its high export importance in the European Union. To the best of our knowledge, there are no previous studies quantifying the effects of a border closure in an imperfectly competitive chain.

The chapter is organized as follows. Section 2 provides a short overview of the Dutch tomato market. Section 3 develops the theoretical model that incorporates trade flows and imperfect competition in the chain. Subsequently, this model is integrated in a partial equilibrium simulation model. Section 4 describes the sources of the data and data processing. The simulated scenarios are presented in section 5. Section 6 discusses the results and assumptions made, and conclusions are drawn in section 7.

3.2 The Dutch tomato market

The Dutch horticulture sector is of huge economic importance, as demonstrated by its large production and export values. Within the Dutch greenhouse horticulture sector, tomatoes are the most important products in terms of production (47%) (CBS and LEI, 2012). In Europe, the Netherlands and Spain are two of the biggest tomato producers. The majority of the Spanish production is available in a period when Dutch production is low. The Dutch tomato supply chain can be, conceptually, broken into three stages: (i) greenhouse tomato producers, (ii) wholesalers and (iii) retailers. Most tomatoes are produced from April to November and are grown mainly in greenhouses. Approximately 95 percent of the tomato production in the Netherlands is exported. The Netherlands exports more tomatoes than produced domestically, and acts as a re-exporter (transit) for tomatoes. Tomatoes are primarily imported in the winter months because of lower production and weather conditions during this season, and to be able to export tomatoes all-year round. The Netherlands has a larger export market share in the summer months, when the output of producing countries such as Spain is low (Bunte, 2009). The most important importers of Dutch tomatoes are Germany and the United Kingdom. Approximately 40 percent of Dutch exports are destined to Germany and 18 percent to the United Kingdom[1].

In the past, prices of Dutch tomatoes were determined at auctions. With the disappearance of the auctions, the Dutch tomato market became less transparent (Galen *et al.*, 2010), and prices still being settled on a short-term basis (Bunte, 2009). The market share of the largest four retailers in the Netherlands is approximately sixty-six percent, whereas the market share is expected to be higher on the purchase side of retailers (Bunte, 2009). In the Dutch tomato supply chain, many producers join wholesale cooperatives which presumably represent the producers' interests in the market for fresh tomatoes.

3.3 Theoretical Framework

Our model captures the vertical structure of the Dutch greenhouse tomato market using a structural model of consumer, retailer and wholesaler behaviour. This framework is based on Sexton *et al.* (2007), but expanded by including export and import flows at the wholesale level. All firms in the chain compete in quantities. Quantity competition enables us to model tomatoes as homogenous products, because imperfect competition in prices requires modelling tomatoes as differentiated products to evade the Bertrand paradox (Tirole, 1989; Carter and MacLaren, 1997).

The domestic aggregate inverse demand function by consumers for Dutch tomatoes can be written as:

$$p_t^r = f\,(Q_t^r, Z_t^r\,), \tag{1}$$

1 Calculations are based on EUROSTAT data (2001-2011).

where p_t^r represents the domestic retail price, Q_t^r represents the quantity demanded and Z_t^r represents various exogenous variables which affect demand. Specifically, Z_t^r may be thought as income per capita or seasonal dummy variables. Because supply of tomatoes in the short-term is inelastic, producer supply is treated as fixed. The international inverse demand function for Dutch tomatoes that wholesalers face, is expressed as:

$$p_{mt}^{ex} = D\,(Q_{mt}^{ex}, Z_{mt}^{ex}) \qquad \{m = 1,2,..M\} \tag{2}$$

where p_{mt}^{ex} denotes the export price to export market, m, Q_{mt}^{ex} and Z_{mt}^{ex} denote the export quantity supplied to market m and demand shifters, respectively.

The starting point of the model is the profit-maximization problem of a Dutch wholesaler who sells tomatoes domestically and internationally. Internationally, wholesalers sell to competitive foreign markets. Because many Dutch tomato producer associations cooperate closely with wholesalers in greenhouse tomatoes, wholesalers are assumed not to have market power over the producers. In addition, Dutch wholesalers purchase tomatoes from competitive foreign suppliers. They import tomatoes for the domestic retail market (twenty percent of the domestic consumption) and, if necessary, for the export markets.

Analytically, the market-level quantities are denoted as $Q^r, Q^{wd}, Q^p, Q^{im}, Q^{ex}$, where the superscripts r, wd, p, im and ex denote the retail, wholesale domestic, producer, import and export stages, respectively. Wholesalers and retailers utilise a fixed-proportion and constant-returns technology to transmit the producer product to the retail stage (Sexton and Zhang, 2001), meaning that the total residual wholesale domestic supply is equal to the total quantity of all retailers $Q_t^{wd} = Q_t^r$. At the equilibrium it holds $Q^r = Q^{wd} = Q^p + Q^{im} - Q^{ex}$. The wholesaler's profit function can then be expressed as[2] (Jacquemin *et al.*, 1980; Huang and Sexton, 1996; Sexton *et al.*, 2007):

$$\begin{aligned} \max_{q_{it}^{wd}, q_{mit}^{ex}, q_{it}^{im}, q_{it}^{p}} \pi_{it}^{w} = {} & (p_t^{wd} - c_{it}^{wd})\, q_{it}^{wd} + \sum_m (p_{mt}^{ex} - c_{mit}^{ex} - \tau_{mt})\, q_{mit}^{ex} - p_t^p q_{it}^p \\ & - (p_t^{im} + c_{it}^{im})\, q_{it}^{im}, \\ & \qquad s.t.\, q_{it}^{wd} + \sum_m q_{mit}^{ex} = q_{it}^p + q_{it}^{im}. \end{aligned} \tag{3}$$

where c_i^{wd} and c_i^{ex} are 'other costs', or handling costs, of wholesaler i per unit of output sold domestically and internationally, respectively. τ_{mt} denotes transportation costs to the export market m. Lastly, p_t^{im} denotes the price of imports and is taken

2 Henceforth the exogenous demand and supply shifters are suppressed.

by the wholesalers as given and c_i^{im} are the costs of wholesaler i per unit of input bought internationally. Taking into account the above relations enables us to write the first-order conditions of (3) as (for detailed derivations, see Huang and Sexton (1996)):

$$p_t^{wd} = p_t^p + c_{it}^{wd}, \tag{4}$$

$$p_{mt}^{ex} = p_t^p + c_{mit}^{ex} + \tau_{mt}, \tag{5}$$

$$p_t^{im} + c_{it}^{im} = p_t^p, \tag{6}$$

From these equations and assuming equal and constant costs in the export and domestic markets[3], the price of export in equilibrium is:

$$p_{mt}^{ex} = p_t^{wd} + \tau_{mt} \qquad \{m = 1,2,..M\}. \tag{7}$$

Dutch wholesalers supply competitively in the export market, meaning that the residual supply to domestic retailers is the total supply (import plus producer supply) minus the amount demanded by foreign markets: $Q_t^{wd} = Q_t^p + Q_t^{im} - \sum_m Q_{mt}^{ex}$. This study considers an oligopolistic and oligopsonistic domestic retail sector:

$$\max_{q_{it}^r, q_{it,}^{wd}} \pi_{it}^r = D(Q_t^r)\, q_{it}^r - S(Q_t^{wd})\, q_{it}^{wd} - c_t^r q_{it}^r, \tag{8}$$

where $S(Q_t^{wd})$ denotes the residual supply function that retailers face from the wholesalers. The first-order necessary condition for maximizing (8) is:

$$p_t^r \left(1 - \frac{\theta^r}{\eta^r}\right) = p_t^{wd} \left(1 + \frac{\vartheta^{wd}}{\varepsilon^{wd}}\right) + c_t^r. \tag{9}$$

$\theta^r = \left(\frac{\partial Q_t^r}{\partial q_{it}^r} \frac{q_{it}^r}{Q_t^r}\right)$ is the retailers' conjectural elasticity measuring the degree of oligopoly power in the retail sector,

$\vartheta^{wd} = \left(\frac{\partial Q_t^{wd}}{\partial q_{it}^{wd}} \frac{q_t^{wd}}{Q_t^{wd}}\right)$ is the retailers' conjectural elasticity measuring the degree of oligopsony power in the retail sector,

$\eta^r = \left(\frac{dQ_t^r}{dp_t^r} \frac{p_t^r}{Q_t^r}\right)$ is the absolute value of the price elasticity of consumer demand, and

$\varepsilon^{wd} = \left(\frac{dQ_t^{wd}}{dp_t^{wd}} \frac{p_t^{wd}}{Q_t^{wd}}\right)$ is the absolute value of the price elasticity of wholesale residual supply.

3 Past literature notes that if firms can exhibit market power, they can increase output while reducing costs, thereby increasing the returns to scale (McCorriston *et al.*, 2001; Sexton *et al.*, 2007). However, it is assumed here that wholesalers will not exhibit market power.

θ^r and ϑ^{wd} denote the conjectural variation elasticities and can both be interpreted as indexes of market power, with $\theta_t^r, \vartheta_t^w \in [0,1]$. The conjectural variation elasticities measure the retailer's oligopsony market power in obtaining the wholesale tomatoes or the retailer's oligopoly power when selling to the consumers. If this elasticity is equal to 1, the retailer sector acts as a monopolist or monopsonist, if the parameter is equal to zero the market is characterized by perfect competition (Sexton *et al.*, 2007). The conjectural variations approach has been largely covered in the literature for imperfect competition and international trade of agricultural products (Carter and MacLaren, 1997).

As this study works with market-level data, aggregation among firms is necessary. Previous literature discussed the possibilities of aggregation (Appelbaum, 1982; Azzam and Pagoulatos, 1990; Wann and Sexton, 1992; Soregaroli *et al.*, 2011). We follow here the framework of Wann and Sexton (1992). Hence, it is assumed that firms have identical technologies, both retailers and wholesalers use a constant-return to scale technology and all firms' conjectures are equal. Conjectural variations measure the overall market reaction to a firm's change in quantity (Appelbaum, 1982; Bresnahan, 1982).

3

Simulation framework

Quantifying the effects of market power, health scares and border closure requires analytical solutions for the market equilibrium. Therefore, it is needed to specify functional forms for the demand and supply functions. In order to get explicit solutions, this study adopts linear functional forms for equations (1) and (2):

$$Q_t^r = a - \beta p_t^r \tag{1'}$$

$$Q_{mt}^{ex} = \gamma_m - \delta_m p_{mt}^{ex} \tag{2'}$$

Wholesalers face the following import supply:

$$p_t^{im} = d + gQ_t^{im} \tag{10}$$

Using the equilibrium conditions (4-7), and the linear functional forms, the residual inverse supply function from domestic wholesalers to domestic retailers that holds in equilibrium is (for detailed derivation, see the Appendix 3A):

$$p_t^{wd} = \left(\frac{gQ_t^p - d - c_{it}^{im} - g\sum(\gamma_m - \delta_m \tau_{mt})}{(1 + g\sum_m \delta_m)} \right) - \left(\frac{g}{(1 + g\sum_m \delta_m)} \right) Q_t^{wd} \tag{11}$$

To simplify notation, the term in the first parenthesis is denoted by h and the term in the second parenthesis by l. Hence, the residual inverse supply function that retailers face can be rewritten as $p_t^{wd} = h + lQ_t^{wd}$. Using the inverse residual supply function and the consumer demand function (1`), the first-order necessary condition for maximizing retailers' profit (9) is:

$$\frac{a - Q_t^r}{\beta} - \frac{Q_t^r \theta_t^r}{\beta} = h + l\,(1 + \vartheta^{wd})\,Q_t^{wd} + c_t^r \tag{12}$$

Because the total residual wholesale domestic supply is equal to the total quantity of the retailers, $Q_t^{wd} = Q_t^r$, equation (12) can be used to solve for Q_t^r:

$$\frac{a - Q_t^r}{\beta} - \frac{Q_t^r \theta_t^r}{\beta} = h + l(1 + \vartheta^{wd})\,Q_t^r + c_t^r \rightarrow Q_t^{r^*} = -\frac{\beta(h + c_t^r) - a}{(1 + \theta^r) + \beta l (1 + \vartheta^{wd})} \tag{13}$$

In our case, the equilibria are determined by, at a minimum, eleven parameters for each period, depending on the number of foreign markets m in the model: $\theta^r, \vartheta^{wd}, a, \beta, \gamma_m, b, d, g, c_t^{wd}, c_t^r$ and Q_t^p. The intercept and slope of the residual wholesale supply function, h and l, are functions of those parameters and the exogenous producer supply quantity. Equation (13) represents the equilibrium condition, in conjunction with equations (1'), (2'), (4)-(7), and (10), that yields equilibrium values for $Q_t^r, Q_{mt}^{ex}, Q_t^{im}, p_t^r, p_{mt}^{ex}$ and p_t^{im}.

Welfare effects

The model can be used to assess the effects of a border closure and market power on welfare distributions among the Dutch greenhouse sector. The change in welfare is the net effect of the change in profits for producers (production side), wholesalers (equation 3) and retailers (equation 8), and potential gains or losses on the consumer side (consumer surplus). However, in the absence of market power and the assumption of equal and constant costs in the export and domestic markets at the wholesale stage, this stage earns zero profits. Changes in consumers' surplus caused by a border closure or health scare can be assessed using the equilibrium prices and quantities before and after the market shock occurs. Consumer surplus (CS) is:

$$CS = \int_0^{Q_t^{r^*}} [D^{-1}(Q) - p_t^{r^*}]\,dQ = \left(\frac{\alpha_t}{\beta_t} - p_t^{r^*}\right) Q_t^{r^*} - \frac{Q_t^{r^*\,2}}{2\beta_t} \tag{14}$$

where $Q_t^{r^*}$ is the equilibrium quantity demanded by consumers and $p_t^{r^*}$ is the equilibrium domestic retail price.

3.4 Parameter estimation

The simulation model requires behavioural parameters to be specified. The relationships outlined in section 3.1 are specified in supply and demand functions which depend on a set of elasticities. The consumer demand (1`), export demand functions (2`) and the import supply equation (3) have been formulated in a linear form and are estimated as single equations using aggregated time-series data.

$$Q_t^r = a_t + \beta_t p_t^r + z_t^r gdp_t^{nl} + z_t D_t,$$

$$Q_{mt}^{ex} = b_t + \gamma_t p_{mt}^{ex} + z_t^{ex} gdp_{mt}^{ex} + z_t D_t, \qquad \{m = GER\ UK\ RW\} \tag{15}$$

$$Q_t^{im} = d_t + g_t p_t^{im} + z_t D_t,$$

The consumer demand function was estimated using weekly data of Dutch tomato retail prices and quantities from 2009 to 2010, a total of 108 observations. Both export and import functions were estimated using monthly data from 2000 to 2010, which gives a total of 132 observations. Because the EHEC crisis occurred in 2011, this year is excluded from the estimation. Monthly import and export data, in both values and quantities, are retrieved from EUROSTAT. The export and import prices are determined from the export and import quantities and expenditures, respectively. Three export markets are distinguished: Germany (GER), United Kingdom (UK), and the Rest of the World (RW). Import data of the 27 countries of the European Union (EU) as one region are used to determine the import price. The retail and export prices are deflated by using the consumer price index (CPI) of the country concerned. Import prices are deflated by using the producer price index of the European Union as one region.

When estimating demand or supply functions, endogeneity problems may arise. Therefore, an instrumental-variables approach is used (Genesove and Mullin, 1998). Endogeneity and overidentifying restrictions are tested using the Durbin-Wu-Hausman and the Sargan tests, respectively. All the regressions include time-fixed effects (month and year dummies), represented by D_t, to account for different developments over time. The Gross Domestic Product (GDP) per capita of the country concerned is deflated and included in the demand equations as a demand shifter, and the energy price index is included in the supply equation as a supply shifter. Estimation results can be found in the appendix (Appendix 3B). Approximately 67 percent of the parameters associated with the endogenous prices were significant at the 0.05 level. To highlight the differences between the production seasons, two elasticities are determined based on the sample mean: one for the high production season (April-September) and one for the low production season (October-March). Table 3.1 shows the mean-based elasticities. The derived elasticities are in the range as found in past studies. Réquillart *et al.* (2008) found higher price elasticities of demand for fresh tomatoes in the winter period than in summer periods. From our estimates, we find higher price elasticities of demand for the domestic and export markets in low production season (winter period) than in the high production season. In the summer period, tomato consumption is higher (also in international markets) and the export markets need a certain amount of tomatoes. Price elasticities of consumer demand in the high production period are found between 0.2 and 0.5, and in the low production season between 0.6 and 1.4 for fresh tomatoes in France (Réquillart *et al.*, 2008), while Padilla-Bernal *et al.* (2001) find price elasticities of consumer demand between 0.5 and 1. The import supply elasticity is very large in the high production period.

Table 3.1 Derived price elasticities of supply and demand

		Low Season	High Season
Demand Elasticities			
η^r	Consumer demand	-0.363	-0.212
η_{ger}	Export demand Germany	-0.885	-0.329
η_{uk}	Export demand UK	-1.046	-0.300
η_{rw}	Export demand RW	-1.218	-0.585
Supply Elasticities			
ε^{im}	Import supply	0.805	3.56
$\varepsilon^{wd\,1}$	Wholesale residual supply	18.6	15.9

[1] $\varepsilon^{wd} = \varepsilon^{im}\frac{Q_t^{im}}{Q_t^{wd}} - \eta_{ex}\frac{\sum_m Q_{mt}}{Q_t^{wd}}$ = average weighted export price elasticity of demand.

From the derived import supply elasticity and price elasticity of export demand, the residual supply elasticity retailers face can be calculated as:

$$\varepsilon^{im}\frac{Q_t^{im}}{Q_t^{wd}} - \eta_{ex}\frac{\sum_m Q_{mt}^{ex}}{Q_t^{wd}}.$$

η_{ex} denotes the average weighted export price elasticity of demand. As shown in Table 3.1, this elasticity is extremely large in both seasons. The quantity supplied to the retailers is much smaller than the quantity exported or imported. Based on the baseline data of year 2010, the quantity tomatoes demanded by the three export markets is approximately 20 times larger than the quantity of tomatoes supplied to the domestic market. The import quantity is, on average, 3 times larger than the quantity consumed in the domestic market (see Table 3.3). In addition, Dutch retailers face competitive Dutch wholesalers, so the wholesalers are sensitive to any price change and have a strong incentive to change their supply to the export or domestic markets, depending on the respective price. The baseline data of year 2010 and the derived elasticities are used for calibrating the equations (1'), (2') and (10). For example, the following calibration calculations are used to derive the consumer demand slope and intercept:

$$\eta_t^r = -\left(\frac{\partial Q_t^r}{\partial p_t^r}\frac{p_t^r}{Q_t^r}\right) = -\left(-\beta\frac{p_t^r}{Q_t^r}\right) \Rightarrow \beta = \eta_t^r\frac{Q_{2010}^r}{p_{2010}^r}, a = Q_{2010}^r + \beta p_{2010}^r.$$

For every production season, intercepts and slopes are calibrated. Using the calibrated β_t, d_t, g_t, b_t and γ_t, parameters of the residual wholesale supply function can be calculated (for full derivation see appendix 3A). The baseline model is calibrated to reproduce all baseline prices and quantities. The export price is used as a proxy for the domestic wholesale price less transportation costs[4]. Following previous studies, transportation costs for vegetables are approximately 1% to 2% of the consumer price (Frugiventa, 2010; Noll *et al.*, 2010), which is in line with our calculations.

3

Besides the parameters, estimates of the conjectural variation parameters were needed. To have an estimate for the conjectural variation of retail oligopsony power, the price cost margin (i.e. Lerner index) is used. The Lerner index measures the amount by which price exceeds its marginal cost (Appelbaum, 1982; Sexton and Lavoie, 2001). With the Lerner indexes one can derive the oligopoly power over consumers (θ_t^r) and the oligopsony power (ϑ_t^{wd}) over wholesalers by the retail sector. However, as can be seen from equation (12), it is not possible to distinguish between the two conjectural parameters. A retail oligopoly market power estimate is, therefore, taken from the literature and the retail oligopsony power parameter is derived by calculating the Lerner index. Dutch wholesaler and retailer costs are derived from the data, the conjectural variation elasticities, and the assumptions in our theoretical framework (equations 4 and 9). Lastly, the fixed producer supply quantity has been derived by the sum of total export and retail quantity minus the imported quantity. Table 3.2 reports the exogenous parameters of the model.

4 Transportation costs are calculated by taking the fuel price, 2011 base data, multiplied by the distance to the market. For the Rest of the World, we have taken Scandinavia (third biggest importer). On average, 14 ton tomatoes are transported by one truck, which consumes 3.5 liters per kilometre.

Table 3.2 Coefficients parameters for the Partial Equilibrium Model

		Low Season	High Season
Conjectural variation elasticities[1]			
θ^r	Retail oligopoly	0.052	0.052
ϑ^{wd}	Retail oligopsony	0.362	0.362
Other variables[1]			
c^r	Handling costs retailers	0.311	0.546
c^{wd}	Handling costs wholesalers	0.427	0.739
c^{im}	Handling costs import	-0.09	-0.576
Q_t^p	Quantity of producer supply	162549.5	602060.2
τ_{Ger}	Transportation costs Germany	0.016	0.016
τ_{UK}	Transportation costs UK	0.027	0.027
τ_{RW}	Transportation costs RW	0.045	0.045

[1] Transportation and handling costs are author's own estimations; θ^r is taken from Réquillart *et al.* (2008), ϑ^{wd} has been calculated by the Lerner index.

3.5 Simulation scenario

The model as described above is used to analyse a series of scenarios reflecting shocks induced by health scare and a border closure. A food crisis such as the EHEC contamination affects the greenhouse horticulture industry by both the demand- and supply side. In addition, the differences between the two seasons (high production period and low season) are considered. Three scenarios are distinguished:

- *Impacts of health scares:* The first scenario (S1) reflects a major health scare which is assumed to cause a reduction in consumer and export demand by 10 percent, while the supply remains the same. Changes in consumer demand for fresh tomatoes are simulated by changing the intercept of the consumer demand function. The intercept is shifted down by 10 percent compared to the baseline model consumer demand intercept. Changes in export demand of Germany, UK and Rest of the World for fresh tomatoes are simulated by changing the intercepts of the export demand functions. The intercepts are also shifted down by 10 percent from the baseline model export demand intercepts.
- *Impacts of a border closure by an export market:* The second scenario (S2) reflects an import ban due to a health scare. Since several import bans took place during

the last decade, this scenario focuses on a border closure by the biggest export market, i.e. Germany. Expected consequences of a drop in the tomato export, are lower producer prices and less imports. By simulating a zero German export quantity in one production period, $Q^{ex}_{GERt} = 0$, the model recalculates the equilibrium quantities and prices.

- *Combinations of a border closure and health scare:* The third scenario combines the two previous scenarios. At the same time, there is a reduction in domestic, Britain and Rest of the World demand while Germany imposes an import ban on Dutch tomatoes.

The simulation model imposes a lower bound for producer prices in case a border closure occurs. This intervention or withdrawal assures Dutch producers that they can sell their total quantity for, at least, the intervention price. The level of the lower bound is set at the percentage of average delivery costs, i.e. 11%, of the producer price (Raes *et al.*, 2011). Each simulation compares the equilibrium solution under each scenario with the baseline situation. Table 3.3 shows the price and quantity values of the baseline situation.

3

Table 3.3 Baseline model quantities and prices

		Low Season	High Season
Dutch Human Consumption (tons)		19027	27982
Consumer price (€/kg)		2.401	2.109
Wholesale price (€/kg)		1.731	1.031
Export quantity (tons)	*Total*	255364	618246
	Germany	117634	255971
	UK	49193	114746
	RW	88537	247529
Export price (€/kg)	*Germany*	1.859	1.271
	UK	1.427	1.132
	RW	1.423	0.982
Import quantity (tons)		111842	13964
Import price (€/kg)		1.083	1.179
Producer price (€/kg)		0.992	0.604

3.6 Results

Table 3.4 reports the results of the simulation of the three scenarios. The results for the first scenario show that the price drops are larger in high (production) season than in low season. The import quantity decreases in high season by approximately 68 percent, while in low season the effect is 19 percent. This difference is explained by the quantity of fixed domestic producer supply. The fixed domestic producer supply is much larger in high season and less import is needed if demand decreases. The total welfare loss of the Dutch tomato chain is 19 and 34 percent in low or high production season, respectively.

An exogenous shock that leads to a border closure by a main import country of Dutch tomatoes, such as Germany, implies a decrease in import quantity and decrease in import, wholesale, retail and producer prices, whereas more tomatoes are exported to other import countries (i.e. UK and the rest of the world) and to the domestic retail market. The effects are larger in high production season (summer) than in low season. The 'rest of the world' (ROW) imports more tomatoes if Germany closes its border than the UK. The ROW has a more elastic price elasticity of demand, meaning that the ROW is more sensitive to price changes and can more easily change its import quantity. In low production season, the Netherlands still import 53 percent of its usual import quantity if a border closure occurs. In high season, however, the import quantity decreases by 100 percent. The total quantity demanded (i.e. for the domestic market and export markets) is higher than the fixed domestic producer supply. In high season, producer prices decrease by 89 percent, meaning that the lower bound is reached (i.e. 11 percent of the baseline price). Producers are guaranteed by selling their quantity, although not all supply is sold to the domestic wholesale market. Part of the domestic produced tomatoes is sold to be destroyed. In low season, producer prices decrease by 57 percent.

Although a border closure in Germany leads to an increase in Dutch human consumption, a border closure combined with a decline in domestic consumer, Britain and ROW demand due to health scare (S3) results into a decrease in consumption and all prices along the chain. Dutch domestic consumption increases by 1 percent. Dutch producers suffer the most from this scenario (S3), i.e.in low season, the producer prices fall by 78 percent and in high season Dutch producers have to sell their tomatoes for the delivery costs price (i.e. 11 percent of the baseline producer price). The loss in total welfare in this scenario is 55 and 68 percent for low and high season, respectively.

A complete welfare evaluation of a border closure or the different market structure requires inclusion of all stages of the chain (Soregaroli *et al.*, 2011). The social welfare changes include changes in consumer welfare, retail profit, wholesale

Table 3.4 Simulation Results (% changes relative to baseline scenario)

		S1[1]		S2		S3	
		Low Season	**High Season**	**Low Season**	**High Season**	**Low Season**	**High Season**
Dutch Human Consumption		-10.17	-9.13	8.12	5.12	-1.80	-6.37
Consumer price		-9.54	-14.11	-22.40	-24.15	-32.58	-27.12
Wholesale price		-11.05	-24.04	-32.79	-52.10	-44.80	-52.10
Export quantity	*Total*	-7.75	-4.47	-21.23	-25.95	-23.76	-34.71
	Germany	-9.75	-6.87	-100	-100	-100	-100
	UK	-6.46	-6.43	41.27	14.24	36.13	1.24
	RW	-5.80	-1.08	48.64	31.99	44.27	16.15
Export price	*Germany*	-10.28	-19.51	–	–	–	–
	UK	-13.41	-21.90	-39.78	-47.46	-54.36	-47.46
	RW	13.43	-25.24	-39.87	-54.69	-54.48	-54.69
Import quantity		-19.42	-68.38	-47.09	-100	-54.55	-100
Import price		-17.63	-21.02	-52.40	-45.55	-71.60	-45.55
Producer price		-19.28	-41.07	-57.21	-89.00	-78.17	-89.00
Total Dutch welfare[2]		-19.29	-34.02	-34.77	-59.33	-55.59	-66.14

[1] S1= Dutch and European consumers change their demand due to health scare; S2= Germany closes its border for fresh Dutch tomatoes; S3= combination of S1&S2.
[2] Total Dutch welfare is the sum of consumer surplus, retail profit, wholesale profit and producer profit.

profits, and producer profits. The changes in export and import quantities and prices are incorporated in the wholesale profits. The largest total welfare losses in the Dutch fresh tomato chain, occur in case Dutch consumers reduce their demand following the health scare and if Germany simultaneously closes its border for Dutch tomatoes. Producer profit is determined by the changes in producer price only, because their output is fixed in the short term. For scenario 2 and 3 in high production season, the producer prices decrease to the minimum harvest costs (delivery costs) of 11 percent of their baseline price.

The conducted scenarios assume no changes in market power of the retailers compared to the baseline model, i.e. $\theta^r = 0.052$; $\vartheta^{wd} = 0.362$. As explained in section 3, the model considers the presence of oligopolistic and oligopsonistic power at the retail level of the Dutch tomato chain. However, due to the very elastic residual supply elasticity (see Table 3.2), oligopsony power does have no or very small impact (see equation 9). Even if Dutch retailers are monopsonists (i.e. ϑ^{wd} =1), the impact will be negligible. The value of the oligopsony power is derived from the baseline data, whereas the value of the oligopoly power is taken from literature. This latter value is based on estimation of French tomatoes. Because it may be the case that in the Netherlands the retail oligopoly estimate is much larger than the one in France or in the Netherlands there exists perfect competition in the retail market, in the following paragraph it is explored how retail oligopoly power can affect total Dutch welfare. In what follows, the sensitivity analyses will focus on the impact of retail oligopoly power only and not on the oligopsony power. Hence, Figure 1 depicts the effect of retail oligopoly power only on total welfare as percentage change compared to the baseline situation, which implies that no health scare or border closure market shocks occur. Perfect competition in the Dutch tomato market implies that Dutch retailers do not have any market power to domestic consumers, i.e. a value of θ^r=0.

Figure 3.1 shows that perfect competition of retailers leads to an increase in total welfare of approximately 0.3-1 percent in high season for the different scenarios respectively. If Dutch retailers are perfectly competitive, the total

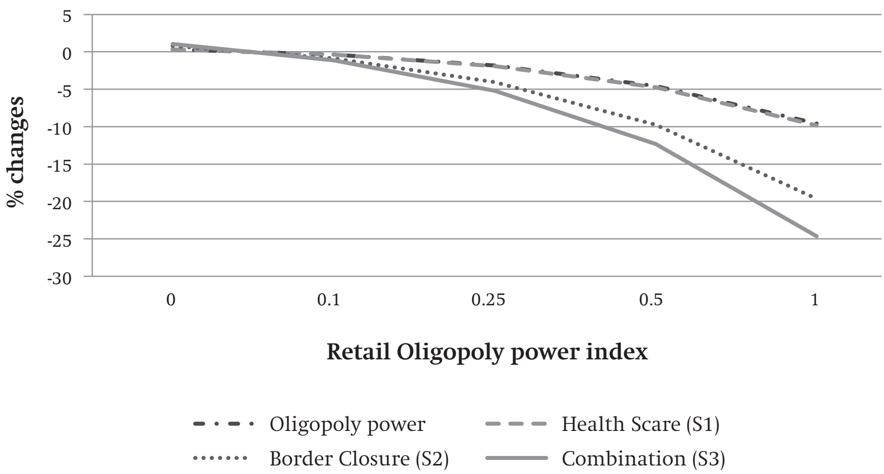


Figure 3.1 The effect of retail oligopoly power on Dutch welfare measured at different scenarios in high season.

welfare increases, compared to the baseline scenario, most when a border closure occurs simultaneously with a health scare. If Dutch retailers are able to exert more power to consumers without any other exogenous shock, the total welfare decreases by approximately 10 percent. Although the effect on total welfare is only 10 percent, Dutch domestic consumer prices increase by more than 100% if the indicator of oligopoly power of retailers takes a value of 0.5. The effects of the different degrees of oligopoly power are more substantial at the consumers and retails. Increasing the oligopoly parameter, θ^r, increases consumer price and decreases domestic human consumption and consumer surplus. Dutch wholesalers experience lower prices to both the domestic retail market as to the export markets, but their quantity to the export markets increases. Because the quantity exported is much higher than the quantity supplied to the domestic market, wholesalers are better off due to higher retail oligopoly power. Dutch producers and import suppliers to the Dutch markets suffer welfare losses from higher oligopoly values as prices and import quantity decrease. In low season the biggest losses in total welfare are during a health scare and a simultaneous border closure.

The results from the analyses suggest that retail oligopoly power has more influence on the total welfare in high season (when more tomatoes are consumed, produced and exported) if no other exogenous shock occurs. This is in line with the results of Table 3.4, where the effects on prices and quantities are larger in high season than in low season. However, if both a health scare and a border closure occur simultaneously, the results on total welfare are the largest in low

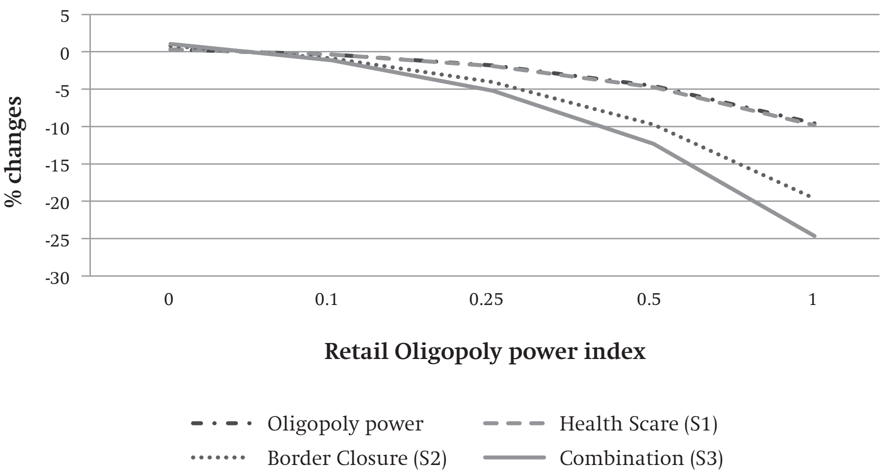


Figure 3.2 The effect of retail oligopoly power on Dutch welfare measured for different scenarios in low season.

season. A border closure has even more impact on total welfare in high season. In high season, Dutch producer prices reach the minimum price (costs of delivery) and their profit drops. The results are graphed in Figure 3.2.

3.7 Discussion & Conclusions

This chapter developed a partial equilibrium model of the market for fresh tomatoes in the Netherlands. A theoretical model of firm behaviour was developed that linked prices throughout the chain, including trade flows and market power at the retail level. The short-term impacts of a decrease in demand in both the domestic and export markets, due to a health scare and the impacts of a border closure are considered. In addition, the chapter examined the sensitivity of the simulation outcomes for different market structures in the Dutch tomato market. A decrease in domestic consumption and decrease in export demand, due to a health scare resulted in a decline in all prices throughout the Dutch tomato chain. Also, a border closure by an important export market, such as Germany, had a negative effect on prices throughout the supply chain. A change in export quantity affected the quantity that wholesalers buy from the import market and domestic producers and resulted therefore in a drop in import prices and producer prices. The effects of all scenarios on supply, demand, prices and welfare were larger in high production season than in low production season.

The results from the empirical model show that as a consequence of health scare and a simultaneous border closure, producer prices decrease almost three times more than retail prices. Dutch producers absorb most of the losses. If a border closure occurs with or without a health scare, in high season, producer prices reach the intervention price. Moreover, the effect of a border closure for imports of Dutch tomatoes had a more significant impact on all prices throughout the chain than a shift in consumer and export demand due to health scare.

The results have shown that in the absence of retail oligopoly power, the total welfare along the Dutch tomato chain gains between 0.3 and 1 percent. If retail oligopoly power increases, the total welfare decreases with approximately 10 percent in the high season. The results also suggested that increases in retail oligopoly power influence all prices along the chain negatively. Given the fact that the residual supply elasticity that Dutch retailers are facing is very elastic, retail oligopsony power has no or only minor impact on prices, quantities and consumer welfare. Dutch domestic tomato consumption is only 5 percent of the total quantity demanded by the export markets which mitigate most of the oligopsony changes in quantity and prices. This is in contrast with the suspicions of policy-makers and producers in the agro-food chain, who claim that retailers use oligopsony power to increase their profits at the detriment of producers or wholesalers.

The theoretical and empirical model developed in this chapter includes a number of assumptions which have implications for the results. Using data of household expenditures could improve the understanding of consumer preferences. However, such data were not available for this study. Our model can be extended to account for competition with other tomato exporting countries such as Spain, Israel and Morocco. Moreover, the model would be enriched if substitution between tomatoes and other vegetables, such as cucumbers or bell peppers, was possible. Finally, the current model focuses on short-term effects. Future research can focus on the long-term effects of a border closure by considering producers' behaviour regarding production, energy use, and investment choices. Then, the model can also account for firms that exit the sector.

Agro-food chains often face shocks like food safety crises (e.g. dioxin contamination) outbreaks of diseases (i.e. foot- and mouth diseases, dioxin, BSE (mad cow disease), and avian influenza). The present chapter shows how health scare, a border closure and imperfectly competitive markets influence the prices, quantities and total welfare along the Dutch tomato chain. Our model can be easily adapted to analyse other chains.

References

Appelbaum, E. 1982. The estimation of the degree of oligopoly power. *Journal of Econometrics* 19: 287-299.

Azzam, A.M. and Pagoulatos, E. 1990. Testing oligopolistic behaviour: an application to the US meat-packing industry. *Journal of Agricultural Economics* 41: 362-370.

Bresnahan, T.F. 1982. The Oligopoly solution concept is identified. *Economics Letters* 10: 87-92.

Brown, J.D. 1969. Effect of a Health Hazard “Scare” on Consumer Demand. *American Journal of Agricultural Economics* 51: 676-678.

Bunte, F. 2009. Prijsvorming glastuinbouw. Nota 09-02.Den Haag: Agricultural Economics Research Insitute (LEI).

Bunte, F. and Kuiper, E. 2008. Promoting Floriculture Using VAT Regulation. *European Journal of Horticultural Science* 73: 248-253.

Carter, C.A. and MacLaren, D. 1997. Price or Quantity Competition? Oligopolistic Structures in International Commodity Markets. *Review of International Economics* 5: 373-385.

CBS and LEI. 2012. Land- en tuinbouwcijfers 2012.’s-Gravenhage Statistics Netherlands (CBS); Agricultural Economics Research Instititute (LEI)

Dahlgran, R.A. and Fairchild, D.G. 2002. The demand impacts of chicken contamination publicity—a case study. *Agribusiness* 18: 459-474.

Frugiventa. 2010. Jaarverslag Frugiventa.

Galen, M., van., Ruijs, M., Dijkxhoorn, Y. and Smit, P. 2010. Bedrijfskolom en marktstructuur van tomaten; Addendum bij ‘Prijsvorming van voedingsproducten’. Nota 11-056.Agricultural Economics Research Institute (LEI).

Garcia-Alvarez-Coque, J.-M., Martinez-Gomez, V. and Villanueva, M. 2010. Seasonal protection of F&V imports in the EU: impacts of the entry price system. *Agricultural Economics* 41: 205-218.

Genesove, D. and Mullin, W.P. 1998. Testing Static Oligopoly Models: Conduct and Cost in the Sugar Industry, 1890-1914. *The RAND Journal of Economics* 29: 355-377.

Hatirli, S.E., Jones, E. and Aktas, A.R. 2003. Measuring the market power of the banana import market in Turkey. *Turkish journal of agriculture & forestry* 27: 367-373.

Henneberry, S.P., Piewthongngam, K. and Qiang, H. 1999. Consumer food safety concerns and fresh produce consumption. *Journal of Agricultural and Resource Economics* 24: 98-113.

Huang, S.-Y. and Sexton, R.J. 1996. Measuring Returns to an Innovation in an Imperfectly Competitive Market: Application to Mechanical Harvesting of Processing Tomatoes in Taiwan. *American Journal of Agricultural Economics* 78: 558-571.

Jacquemin, A., Ghellinck, E.d. and Huveneers, C. 1980. Concentration and Profitability in a Small Open Economy. *The Journal of Industrial Economics* 29: 131-144.

Just, R.E. and Chern, W.S. 1980. Tomatoes, Technology, and Oligopsony. *The Bell Journal of Economics* 11: 584-602.

Kaditi, E.A. 2011. Market Dynamics in Supply Chains: The impact of globalization and consolidation on food Companies’ mark-ups. LICOS Centre for Institutions and Economic. Discussion Paper 273/2011. Katholieke Universiteit Leuven.

Lloyd, T., McCorriston, S., Morgan, C.W. and Rayner, A.J. 2001. The impact of food scares on price adjustment in the UK beef market. *Agricultural Economics* 25: 347-357.

Malaga, J.E., Williams, G.W. and Fuller, S.W. 2001. US-Mexico fresh vegetable trade: the effects of trade liberalization and economic growth. *Agricultural Economics* 26: 45-55.

Melnick, R. and Shalit, H. 1985. Estimating the Market for Tomatoes. *American Journal of Agricultural Economics* 67: 573-582.

Noll, R., van der, Baarsma, B. and Roosenboom, N. 2010. Van teelt tot schap, Waardecreatie door de groothandel in groenten en fruit. SEO-rapport nr. 2010-74.SEO Economisch Onderzoek.

Padilla-Bernal, L., Thilmany, D. and Loureiro, M. 2001. Tradability and market equilibrium for US-Mexico fresh tomatoes. *Journal of Agricultural and Resource Economics* 26: 567-567.

Piggott, N.E. and Marsh, T.L. 2004. Does Food Safety Information Impact U.S. Meat Demand? *American Journal of Agricultural Economics* 86: 154-174.

Product Board Horticulture. 2011. Marktbeeld Tomaat.
Raes, W., Bernaerts, E., Demuynk, E., Oeyen, A. and Tacquinier, B. 2011. Economische resultaten van de Vlaamse land- en tuinbouw.Afdeling Monitoring en Studie Vlaamse overheid
Réquillart, V., Simioni, M. and Varela Irimia, X. 2008. Imperfect competition in the fresh tomato industry. Paper presented at: EAAE International Congress, Ghent, Belgium, August 26 - 29.
Rickard, B.J. and Sumner, D.A. 2008. Domestic Support and Border Measures for Processed Horticultural Products. *American Journal of Agricultural Economics* 90: 55-68.
Roosen, J., Lusk, J.L. and Fox, J.A. 2003. Consumer demand for and attitudes toward alternative beef labeling strategies in France, Germany, and the UK. *Agribusiness* 19: 77-90.
Serra, T. 2011. Food scare crises and price volatility: The case of the BSE in Spain. *Food Policy* 36: 179-185.
Sexton, R.J. and Lavoie, N. “Food processing and distribution: An industrial organization approach”, in B.L. Gardner and G.C. Rausser (eds.), *Handbook of Agricultural Economics*: Elsevier, 2001, 863-932).
Sexton, R.J., Sheldon, I., McCorriston, S. and Wang, H. 2007. Agricultural trade liberalization and economic development: the role of downstream market power. *Agricultural Economics* 36: 253-270.
Sexton, R.J. and Zhang, M. 2001. An assessment of the impact of food industry market power on U.S. consumers. *Agribusiness* 17: 59-79.
Soregaroli, C., Sckokai, P. and Moro, D. 2011. Agricultural policy modelling under imperfect competition. *Journal of Policy Modeling* 33: 195-212.
Tirole, J. 1989. *The theory of industrial organization*. Cambridge [etc.]: MIT.
van der Kolk, T., 2011. EHEC: angst is voorbij, onduidelijkheid blijft. Volkskrant. 22 June.
Vavra, P. and Goodwin, B.K. 2005. Analysis of Price Transmission Along the Food Chain. Food, Agriculture and Fisheries Working Papers. no 3.OECD.
Verreth, D.M.I., Bunte, F. and Oude Lansink, A.G.J.M. 2011. Modelling Market Environment Changes in the Horticulture Sector - A Review. *European Journal of Horticultural Science* 76: 22-30.
Wann, J.J. and Sexton, R.J. 1992. Imperfect Competition in Multiproduct Food Industries with Application to Pear Processing. *American Journal of Agricultural Economics* 74: 980-990.
Zweers, A., 2004. Douane weert half miljoen euro aan Nederlandse bloemen per dag om miniem insect. NRC Handelsblad. 30 June.

Appendix 3A

Derivation residual wholesale supply function

$$Q_t^{wd} = Q_t^p + Q_t^{im} - \sum_m Q_{mt}^{ex}.$$

$$Q_t^{wd} = Q_t^p + \frac{p_t^{im} - d}{g} - \sum_m (\gamma_m - \delta_m p_{mt}^{ex})$$

Use (4), (6) and (7):

$$Q_t^{wd} = Q_t^p + \frac{p_t^{wd} - d - c_t^{im}}{g} - \sum_m (\gamma_m - \delta_m (p_{mt}^{wd} + \tau_{mt})$$

$$Q_t^{wd} = Q_t^p + \frac{-d - c_t^{im}}{g} - \sum_m (\gamma_m - \delta_m \tau_{mt}) + p_t^{wd} \left(\frac{1}{g} + \sum_m \delta_m \right)$$

Inverse form:

$$gQ_t^{wd} = gQ_t^p + p_t^{wd} - d - c_t^{im} - g \sum_m (\gamma_m - \delta_m (p_{mt}^{wd} + \tau_{mt})$$

$$gQ_t^{wd} - gQ_t^p + d + c_t^{im} + g \sum_m (\gamma_m - \delta_m (\tau_{mt}) = p_t^{wd} (1 + g \sum_m (\delta_m)$$

$$gQ_t^{wd} = gQ_t^p + -d - c_{it}^{im} + g \sum_m (\gamma_m - \delta_m \tau_{mt}) + p_t^{wd} (1 + g \sum_m \delta_m)$$

$$p_t^{wd} =- \frac{gQ_t^p - d - c_{it}^{im} + g \sum (_m \gamma_m - \delta_m \tau_{mt})}{(1 + g \sum_m \delta_m)} + \frac{g}{(1 + g \sum_m \delta_m)} Q_t^{wd}$$

Derivation residual retail supply function

$$p_t^r - \frac{Q_t^r \theta_t^r}{\beta} = p_t^{wd} + l\vartheta^{wd} Q_t^r + c_t^r$$

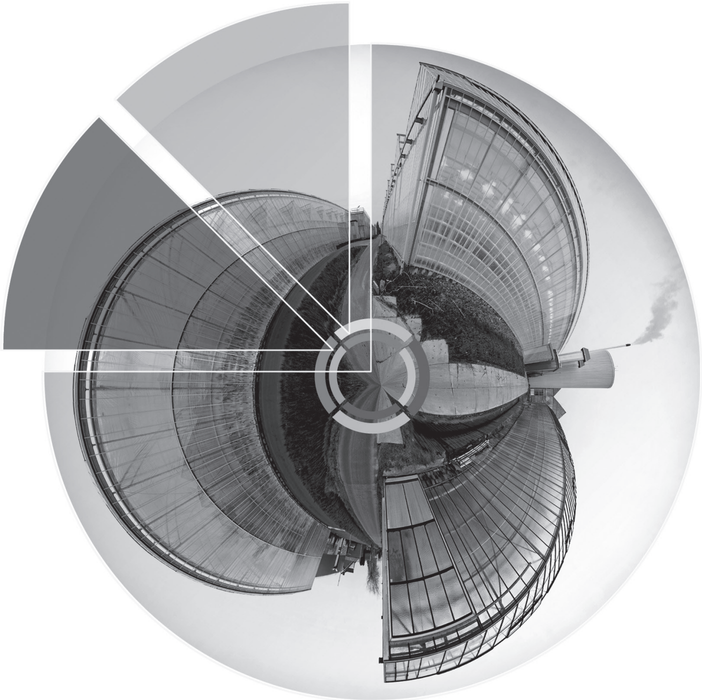
$$\frac{\beta(p_t^r - p_t^{wd} - c_t^r)}{\beta l \vartheta^{wd} + \theta_t^r} = Q_t^r$$

Appendix 3B

Table 3B Regression estimates

	Q_t^r	$Q_{ger\,t}^{ex}$	$Q_{uk\,t}^{ex}$	$Q_{rw\,t}^{ex}$	Q_t^{im}
p_t^r	-109302.6**				
gdp_t^{nl}	820.7				
p_{mt}^{ex}[1]		-10846.8	-4074.235 **	-12721.7**	
gdp_{mt}^{ex}		22.89996	-.8147144	-.08	
p_t^{im}					18778.2
X_t^{im}[2]					70.9
dum2001		-1571.8	-309	-2706.3	-83.3
dum2002		-329.3	1351.8*	902.2	-2574
dum2003		-782.1	2006**	2048.2	-7075.5
dum2004		125.6	3493.1**	3882.9	-6243.1*
dum2005		1149.7	4212.1**	6777.1**	-3571.1
dum2006		3275.9*	3671.9**	7056.5	-10876.5
dum2007		3096.7	2520.8**	10672.7*	-22035.8**
dum2008		6011	2919.8**	9778**	-27488.1**
dum2009		6567.9**	2934.4**	13055.8**	18007.5**
dum2010	29427.1[3]	4827.2	2926.5***	15430.9**	-23054.8**
February	-38621.5	-2776.4*	102.3	-1183.2	-4453.1
March	73878.5	4356.3**	2574.1**	5271.7**	-11372.5**
April	204714.1**	14636.7**	7056.6**	9985.9**	-23626.8**
May	312559.9**	24550.3**	9793.6**	15094.7**	-27456.8**
June	468321**	25139.2**	12855.5**	17999.8**	-32633.9**
July	384771.7**	27370.4**	15289.9**	16973.2**	-39314.5**
August	360437.5	16655.3**	13410.1**	12522.7**	-47189.3**
September	392440.1	13305.3**	10667.6**	9702.1**	-82555.8**
October	125573.3	10972**	9378.3**	7454.8**	-51327.4**
November	168830.9*	5389.2**	2641.9	3841	-25703.1**
December	112860.3	820.5	1086.5	4022.4	-6947*
Constant	421913.4	-22171.1	10505.4	19539.2	26273.1**
R^2	0.55	0.92	0.95	0.95	0.85

[1] m = Germany, UK and ROW respectively; [2] X_t^{im} Import supply shifter (energy price index);
[3] Consumer demand regression is based on weekly data of the years 2009 and 2010 only.
* denotes 10% significance level; ** denotes 5% significance level



4

Price Transmission, international trade and asymmetric price relationships in the Dutch agro-food chain

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Submitted.

Abstract

This chapter analyses the response of producer, wholesale, retail and international trade prices to shocks in prices in upstream or downstream stages in the Dutch onion and red pepper supply chains. The analysis allows for asymmetric adjustment among food prices when the wholesale or retail stages exert oligopoly power. The study provides a theoretical underpinning of the relationship between domestic and international prices. Asymmetries in price transmission are examined using the Houck approach as well as the error-correction approach. The impulse response analyses show that red pepper prices return to their long-term equilibria relatively quickly, whereas onion prices settle at a new equilibrium after a price shock. Market power in the wholesale sector affects the responses of onion prices but has little or no effect on the responses of red pepper prices. Market power in the retail sector does not affect the onion prices or the red pepper prices. Analysis of weekly price data over the period from 2005 to 2008 suggests asymmetric adjustment in producer-wholesale and international trade–producer relationships in the Dutch onion supply chain. The results also show asymmetric transmission between producer prices and retail prices of red pepper.

Keywords: Asymmetry; Time series models; Price transmission; Market power; Agro-food chain.

4.1. Introduction

The Dutch horticulture sector has undergone important changes in recent years. While the number of firms at every stage of the chain has decreased, there has been a simultaneous increase in production, and export and import quantities. The increasing concentration of firms at the retail stage over the last few decades has led to larger companies with larger market shares. The top four retail firms currently account for 65–75 percent of the vegetable market. Furthermore, the four largest vegetable wholesalers account for approximately 50 percent of the domestic market (Bunte, 2009; NMa, 2009). In 2012, the Netherlands Authority for Consumers and Markets (ACM) fined three red pepper wholesale/producer cooperatives that had formed a price cartel to keep wholesale prices high. Besides, the ACM fined producers of onion sets who reduced the onion supply to increase prices (NOS, 2012; NMa, 2013). The imperfect price transmission from producers to wholesalers to consumers resulting from retailer or wholesaler concentration may have serious long-term effects on consumers and upstream suppliers (Sexton *et al.*, 2007). In the case of red peppers, wholesalers may have exerted seller power on retailers. As a result, Dutch consumers and consumers in Germany and the UK, which import high volumes of red peppers, have likely paid too high prices for red peppers in recent years (NOS, 2012). Policy-makers are often concerned about potential welfare losses attributable to high market concentration (Vavra and Goodwin, 2005; Sexton and Zhang, 2001).

The analysis of vertical asymmetric price transmission provides insight into the price relationships between the different stages in the supply chain and shows how changes in a specific link of the chain are transmitted to upstream and downstream stages. The extent and speed at which exogenous shocks are transmitted between the different levels of the supply chain may reflect the level of competition in the market (Serra and Goodwin, 2003). Retail prices tend to respond more quickly and fully to producer price increases than to producer price decreases (Borenstein *et al.*, 1997; McCorriston *et al.*, 1998; McCorriston *et al.*, 2001; Meyer and von Cramon-Taubadel, 2004). Price transmission depends on competition at all levels of the supply chain. Therefore, a study on the relationship between price transmission and possible market power should cover all levels of the chain. The relevance of the existing literature on price transmission in the fruit and vegetable supply chain is restricted by the number of levels of the chain (Goetz et al., 2008; Just and Chern, 1980). Many studies only include producer and consumer prices (Melnick and Shalit, 1985; Réquillart et al., 2008; Mesa and Gómez, 2011) or import and consumer prices for tropical fruits (Hatirli et al., 2003). Meyer and von Cramon-Taubadel (2004) conducted an extensive survey of the existing literature on price transmission. They also concluded that the theoretical foundation of price transmission studies receives too little attention.

Several horticultural markets such as tomatoes, onions and fresh vegetables, have also been found to exhibit asymmetric price transmission between the producer and retail levels, or between wholesale and retail levels (Ward, 1982). For a detailed review see Frey and Manera (2007). Gardner (1975) identified factors that influence asymmetric price transmission between the producer and retail sectors. Market power and market concentration may cause asymmetric price transmission (Peltzman, 2000; Lloyd *et al.*, 2001). In addition, firms may face different adjustment costs depending on whether prices are rising or falling (DeeVon and Brorsen, 1989). Other factors include menu costs at the retail level (Azzam, 1997) and supply or demand shocks, such as disruptions from international trade (Gardner, 1975). Free trade enhances price transmission (Goetz *et al.*, 2008). As Ward (1982) noted, the price transmission of perishable products may be asymmetric, because actors want to avoid the risk of being left with spoiled products.

Prior literature applied several different methodological approaches to measuring the degree of asymmetric price transmission. Earlier empirical procedures developed by Wolffram (1971) or Houck (1977) focused on differences in responses of aggregate supply functions to positive and negative changes in prices. Both disregarded the time series properties of the data and, therefore, may be biased (von Cramon-Taubadel, 1998). The current study takes into account the fact that price time series are often non-stationary. Consequently, producing spurious results can be avoided (Granger and Newbold, 1974). Time series models, such as the Vector Error Correction Model (VEC), address possible deviations from the long-term equilibrium.

The aim of this study is to examine the vertical price transmission in the Dutch vegetable market and infer whether price adjustments are asymmetric. The study concentrates on the relationships between domestic prices in all stages of the horticulture supply chain (that is, producer, wholesale and retail prices) and includes the effect of international trade prices. A theoretical model is developed to support the estimation of prices using price time-series models. Using detailed weekly price data enables to study the effects in the short and long term of price shocks at multiple levels of the chain.

This study contributes to the agricultural economics literature by providing a theoretical underpinning of the relationship between domestic and international trade prices in the Dutch agro-food supply chain. Moreover, the framework developed estimates the possible asymmetric behaviour of actors in the Dutch onion or red pepper chain and is able to use a unique data set comprising of all observed prices. To the best of the authors' knowledge, no previous studies have analysed the degree of asymmetric price transmission at all possible levels of the fresh vegetables supply chain.

The empirical application focuses on the markets of onions and red peppers in the Netherlands. These markets are analysed because of the recent Dutch market developments (the red pepper wholesalers received a fine from the regulatory authority (ACM) and because of data availability. In addition, one can examine whether the production characteristics of the vegetables influences price transmission. Namely, in terms of production, red pepper is one of the most important greenhouse horticulture products, whereas onions are one of the most significant exported, open-field produced products. Furthermore, onions have limited perishability and are harvested only once a year. On the other hand, red peppers are highly perishable and harvested throughout the year.

The structure of the remainder of this chapter is as follows. Section 2 provides an overview of the Dutch onion and red pepper markets. Section 3 develops the theoretical model for examining price responses to shocks in market concentration in the Dutch (greenhouse) vegetable chain. Section 4 specifies the empirical model. Section 5 describes the data sources and data processing. Section 6 presents the results. Section 7 gives some policy tools, and conclusions are drawn in section 8.

4.2 The Dutch horticulture market

The Dutch horticulture sector plays an important role in the supply and export of fresh fruit and vegetables. In the winter months, the Netherlands acts as a re-exporter (transit) for vegetables such as tomatoes, peppers and cucumbers. Within the Dutch greenhouse horticulture sector, tomatoes, red peppers and cucumbers are the most important commodities in terms of production. In open-field, onion is a significant export commodity. Ninety percent of domestic onion production is exported, whereas imports satisfy only 15 percent of domestic demand. The Netherlands is the world's largest exporter of onions and has approximately 15 percent share of total world onion exports. Red peppers are primarily imported in the winter months because of lower production.

Larger companies with larger market shares have led to an increasing concentration of retailers. The market share of the four largest retailers in the Netherlands is approximately 65-75 percent, whereas the market share is expected to be higher on the purchase side of retailers (Bunte, 2009). The four largest wholesalers that sell fruit and vegetables account for approximately 50 percent of the market (Bunte, 2009; NMa, 2009). In the Dutch red pepper supply chain, many producers associations cooperate closely with wholesalers in greenhouse fruit and vegetables. Producers and wholesalers act together to serve joint interests. This is different in the market for onions. Approximately 10 percent of onions are grown against a fixed contract price. Most of the onions are sold on the free market, but pool prices also exist. Within those pools, onions are sold at an average price. The characteristics and developments in the Dutch fresh vegetable sector suggest that

Dutch wholesalers are able to transmit prices asymmetrically to the retailers and, therefore, put extra margin on their prices.

4.3 Theoretical Framework

This section examines the vertical relationship between producers, wholesalers and retailers in the Dutch fresh vegetable market. This study considers an oligopolistic retail sector in which *N* firms sell homogenous vegetables to consumers. The retailers buy onions or red peppers from the upstream wholesale market, and wholesalers buy vegetables from domestic producers and international markets. It is assumed that no losses occur when vegetables are moved along the supply chain. Consequently, wholesalers and retailers utilise a fixed-proportion and constant-returns to scale technology to transmit the producer product to the next stage (Sexton and Zhang, 2001)[1]. The theoretical model starts from an inverse consumer demand function, given by:

$$P^r = D(Q^r, Z^r), \tag{1}$$

where Q^r is the market quantity at the retail level, P^r is the price that consumers face and Z^r denotes exogenous demand shifters. The inverse supply function of the producers is given by:

$$P^p = S(Q^p, X^p), \tag{2}$$

where the producer price P^p depends on the total quantity supplied, Q^p, and exogenous supply shifters, X^p. Following the Dutch market characteristics, it is assumed that both wholesalers and retailers maximise their profits. In this case, it is assumed that wholesalers behave as vertical prices leaders with respect to Dutch retailers. In the domestic retail market, each food retailer i maximizes its profit and takes the wholesale domestic price P^{wd} as given. Subsequently, the domestic wholesaler i determines its quantity (Kuiper and Meulenberg, 2002; Kuiper *et al.*, 2003) while taking into account the retailer's behaviour.

$$\max_{q_i^r} \pi_i^r = D(Q^r)\, q_i^r - P^{wd} q_i^r - c_i^r q_i^r, \tag{3}$$

1 Past literature notes that caution should be exercised in the constant-returns-to-scale assumption. Increasing returns to scale leads to increasing output while reducing costs. This results into a greater degree of price transmission (McCorriston *et al.*, 2001).

where $Q^r = \sum_{i=1}^{n} q_i^r$. Additionally, c_i^r are handling costs of retailer i per unit of output and P^{wd} represents the price of the wholesaler. The first-order condition for maximising profit implies (for detailed derivations, see Sexton et al. (2007) and Lloyd et al. (2006)):

$$\frac{d\pi_i^r}{dq_i^r} = P^r + q_i^r P^{r'}(Q^r)\frac{dQ^r}{dq_i^r} - P^{wd} - c_i^r \tag{4}$$

This can be rewritten in elasticity notation as:

$$P^r\left(1 - \frac{\theta^r}{\eta^r}\right) = P^{wd} + c^r \Rightarrow P^{wd}(Q^r|\eta^r, \theta^r, c^r), \tag{4'}$$

where $\theta^r = \left(\frac{\partial Q_t^r}{\partial q_{it}^r}\frac{q_{it}^r}{Q_t^r}\right)$ is the retailers' conjectural elasticity measuring the degree of oligopoly power in the retail sector and $\eta^r = -\left(\frac{dQ^r}{dP^r}\frac{P^r}{Q^r}\right)$ denotes the price elasticity of demand. Conjectural variations can be interpreted as the steady state of a dynamic game (Friedman and Mezzetti, 2002; Dixon and Somma, 2003) and measure the overall market reaction to a firm's change in quantity (Appelbaum, 1982; Bresnahan, 1982). The conjectural variation elasticity can be interpreted as an index of conduct, with $\theta_t^r \in [0,1]$. The conjectural variation elasticity measures the retailer's oligopoly market power when selling the vegetables to consumers. If this elasticity is equal to 1, the retailer sector acts as a monopolist, while if the parameter is equal to zero the market is characterized by perfect competition (Sexton *et al.*, 2007). The conjectural variations approach has been largely covered in the literature for imperfect competition and international trade of agricultural products (Carter and MacLaren, 1997).

As this study uses market-level data, aggregation among firms is necessary. Past literature discussed the possibilities of aggregation (Appelbaum, 1982; Azzam and Pagoulatos, 1990; Wann and Sexton, 1992; Soregaroli *et al.*, 2011). This study follows the framework of Wann and Sexton (1992); where, all firms' conjectural elasticities are equal.

Wholesaler i maximizes individual profit while taking the profit-maximizing behaviour of retailers into account. In addition, international trade is assumed to occur at the wholesale level of the horticulture supply chain. Subsequently, wholesalers sell to the domestic retail market and to competitive foreign importers. Analytically, the market level quantities are denoted as, $Q^r, Q^{wd}, Q^p, Q^{im}, Q^{ex}$, where the superscripts *r, wd, p, im* and *ex* denote the retail, wholesale domestic, producer, import and export levels, respectively. At the equilibrium, it holds that $Q^r = Q^{wd} = Q^p + Q^{im} - Q^{ex}$. In the long term, wholesalers can choose how much they purchase from producers and how much they will sell to the domestic and international markets. The wholesaler's profit function can then be expressed as follows (Jacquemin *et al.*, 1980):

$$\max_{q_i^{wd},q_i^{ex}} \pi_i^{w} = P^{wd}(Q^r|\eta^r, H^r, mc^r)\, q_i^{wd} + P^{ex} q_i^{ex} - P^p q_i^p - P^{im} q_i^{im} - c_i^{wd} q_i^{wd} - c_i^{ex} q_i^{ex} \quad (5)$$

where c_i^{wd} and c_i^{ex} are handling costs of wholesaler i per unit of output sold domestically and internationally, respectively, P^{ex} denotes the export price and P^{im} denotes the price of imports. Furthermore, for every wholesaler, it holds:
$q_i^{wd} + q_i^{ex} = q_i^p + q_i^{im}$.
Taking into account the above relations enables us to write the first-order conditions with respect to the domestic wholesale quantity and export quantity of (5) as follows (for detailed derivations, see Huang and Sexton (1996)):

$$P^{wd}\left(1 - \frac{\theta^{wd}}{\eta^{wd}}\right) = P^p + c_i^{wd}, \quad (6)$$

$$P^{ex} = P^p + c_i^{ex}, \quad (7)$$

$$P^p = P^{im} - c_i^{im}. \quad (8)$$

$\theta^{wd} = \left(\frac{\partial Q_t^{wd}}{\partial q_{it}^{wd}} \frac{q_{it}^{wd}}{Q_t^{wd}}\right)$ is the wholesalers' conjectural elasticity measuring the degree of oligopoly power in the wholesale sector, and

$\eta^{wd} = \left(\frac{dQ^{wd}}{dP^{wd}} \frac{P^{wd}}{Q^{wd}}\right)$ is the absolute value of the price elasticity of demand by domestic retailers.

Assuming constant demand elasticities and equal conjectural variation elasticities allows us to treat the terms $\frac{\theta^r}{\eta^r}$ and $\frac{\theta^{wd}}{\eta^{wd}}$ as constants (unknown parameters). The price relations (equations (4'), (6), (7) and (8)) are of interest to this study. If the market is characterized by perfect competition, the conjectural elasticity θ^r approaches zero and the term involving θ^r disappears (equation (4')). If this is the case, the retail price is equal to the domestic wholesale price plus marginal costs (constant). The domestic wholesale price (equation (6)) depends on the producer price and the conjectural elasticity term. If wholesalers form competitive conjectures (θ^{wd} =0) then the domestic wholesale and the producer price plus marginal costs (constant) are equal. To examine whether wholesalers are prices leaders and exert market power, one can consider the long-term equilibrium relationship between the wholesale and retail prices and test whether wholesale prices and retail prices respond to deviations from the equilibrium. The empirical framework describes firstly how prices behave in the short-term consistent with a long-term cointegration relationship. Subsequently, these relationships are tested for asymmetric price adjustment. In the context of vertical price transmission, asymmetry usually refers to differences in the speed of adjustment of price transmission that depends on whether prices are increasing or decreasing. For example in the Dutch red pepper market, it is suspected that when the retail red pepper prices increase, wholesalers increase their prices more rapidly or pass the increase more completely to retailers than corresponding decreases in the retail red pepper prices. This suspicion is generally based on concerns about concentration and imperfect competition in the chain or the perishable characteristics of red peppers.

4.4 Empirical Framework

The price equations derived from the theoretical framework reflect long-term equilibria. However, short-term deviations from these long-term equilibria may be observed. Prices series often contain common characteristics, such as stochastic trends. The first step when analysing time series data is, therefore, to test for stationarity, that is, whether the mean, standard deviation, and covariance are invariant over time (Enders, 2004). Price time series often include a unit root which may produce misleading estimates and spurious results. The Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests are applied to test for stationarity with the null hypothesis that each time serie is stationary. For the tests, it is important to specify the lag length. This study uses the Akaike Information Criterion (AIC) to determine the lag length. If a time series is stationary at level, then it is said to be integrated of order zero [i.e., $I\ (0)$]. However, if it requires first order differencing to be stationary, then it is said to be integrated of order one [$I\ (1)$].

Johansen's approach is employed to test the presence of cointegration of the variables (Johansen and Juselius, 1992; Johansen, 1995). That is, if the price series are integrated of the same order – i.e $I\ (d)$[2] – and there exists a linear combination of them that is stationary, that is, $I\ (0)$. If the presence is confirmed, then the Engle and Granger error correction specification (1987) can be applied to determine Granger causality. To quantify price adjustment, the vector error correction model (VECM) is a suitable framework. The function of the VECM is to describe how prices behave in the short-term consistent with a long-term cointegration relationship. It is a dynamic model in which the change of the prices in any period is related to the previous deviation from the long-term equilibrium. The model can be written in an error-correction form; that is, as a model:

2 The order of integration is the number of times that a series must be differenced before it becomes stationary.

$$\Delta \boldsymbol{P}_t = \pi \boldsymbol{P}_{t-1} + \sum_{i=1}^{p-1} \boldsymbol{\Gamma}_i \Delta \boldsymbol{P}_{t-i} + \Theta \boldsymbol{D}_t + \boldsymbol{\varepsilon}_t, \tag{9}$$

$$\boldsymbol{P}_t = [P_t^r \quad P_t^{wd} \quad P_t^{ex} \quad P_t^{im} \quad P_t^p]',$$

where Δ is the first difference operator and $\boldsymbol{P}_t$ is a $kx1$ vector of the price variables (*I (1)*). The matrix π contains the cointegration relationships and determines the long-term dynamic properties of the price series, $\boldsymbol{D}_t$ is a vector of exogenous variables that may include, for example, linear time trends and seasonal dummies, and $\boldsymbol{\varepsilon}_t$ is a vector of normally independently and identically distributed errors with zero means and constant variances. If there exist cointegration relationships (equations (4'), (6), (7) and (8)), π can be written as a product of the *(kxr)* matrix $\boldsymbol{\alpha}$ and the (*rxk*) matrix $\boldsymbol{\beta}'$ with $\pi = \boldsymbol{\alpha\beta}'$ (Lütkepohl, 2005). The rank, *r*, of the transition matrix can give us an indication of whether the prices of the chain are related. The cointegrating vector $\boldsymbol{\beta}$ quantifies the cointegrating relationships between the producer, wholesale, international trade or retail prices, and the matrix $\boldsymbol{\alpha}$ contains the error correction coefficients indicating the speed of price adjustments when the cointegration equation is out of equilibrium. The short-term effects of shocks on $\Delta \boldsymbol{P}_{t-i}$ are captured by $\boldsymbol{\Gamma}_i$. If no long-term cointegration relationships exist in market prices, π equals zero.

In the case that all prices are stationary, i.e. *I (0)*, the equilibrium error has no unique property if it is *I (0)* (Engle and Granger, 1987). In this case, equation (9) is represented as a Vector Autoregressive (VAR) model. VAR models simultaneously estimate systems of equations and can be used as a general framework for describing the dynamic interrelationship among stationary price variables. The VAR model intends to determine the interrelationship between the endogenous variables $P_t^r, P_t^{wd}, P_t^{ex}, P_t^{im}$ and P_t^p.

$$\boldsymbol{P}_t = \boldsymbol{\mu} + \Gamma_1 \boldsymbol{P}_{t-1} + \Gamma_2 \boldsymbol{P}_{t-2} + \cdots + \Gamma_p \boldsymbol{P}_{t-p} + \Theta \boldsymbol{D}_t + \boldsymbol{\varepsilon}_t, \tag{10}$$

where $\boldsymbol{P}_t$ and $\boldsymbol{D}_t$ were defined under equation (9) and $\boldsymbol{\mu}$ is a vector of constants. The VAR model in (10) is also based on the assumption that the responses of prices are symmetric.

VAR and VEC models are both useful forecasting tools. Both models allow for the evaluation of the time-paths of adjustment to the variables in response to shocks in each of the series. These time-path responses are also called impulse responses (Brester and Goodwin, 1993). Standard impulse responses are derived to evaluate the relationships among the various stages in the chain (Koop *et al.*, 1996). As discussed in Hamilton (1994), an impulse-response function (IRF) describes the effect of a primitive impulse on $\boldsymbol{P}_{t+i}$. The IRFs quantify the responses over time in all of the endogenous variables of a unit shock restricted to one specific endogenous variable at a particular time *t*, keeping everything else constant. IRFs are used to compute the number of periods, or the long-term responses, that a dependent variable needs to return to an equilibrium level once a shock has occurred (Koop *et al.*, 1996). The response is portrayed in graphs, with time on the horizontal axis and the price response on the vertical axis. Standard impulse responses are used which do not allow for asymmetric responses to shocks. Note, that with cointegrated relationships and non-stationarity, one-time shocks may lead to permanent changes in the equilibrium (Lütkepohl and Reimers, 1992; Goodwin and Holt, 1999; Goodwin, 2006).

Asymmetric price transmission approaches

Although the VECM examines whether prices move together in the long term, an asymmetric model provides more insights into the dynamics of price transmission. It provides a measure of deviation from the long-term equilibrium and allows explicit testing of asymmetric transmission (Digal, 2010). The VECM in equation (9) is linear, because the dependent prices are assumed to react linearly to changes in the right-hand-side variables (Hassouneh *et al.*, 2012). Adjustment of prices induced by deviations from the long-term equilibrium are assumed to be continuous and a linear function of the magnitude of the deviation from long-term equilibrium. To account for non-linear responses, models with price adjustment including thresholds, with the error-correction term (ECT) as the threshold variable, are used. The price adjustment process may be different if deviations are above or below a specific threshold. Asymmetry in price transmission is present if the null hypothesis, that the estimated coefficients of the respective positive and negative variable are equal, is rejected by an F-test. To test for asymmetry, von Cramon-Taubadel (1998) proposed segmenting the ECT_t term into ECT_t^+ and ECT_t^-. ECT_t^+ contains the positive, and ECT_t^- the negative, lagged residuals of the long-term equilibrium regression.

$$ECT_t^+ = \begin{cases} ECT_t \; if \; ECT_t > 0 \\ 0 \; if \; ECT_t \leq 0 \end{cases}$$

$$ECT_t^- = \begin{cases} ECT_t \; if \; ECT_t \leq 0 \\ 0 \; if \; ECT_t > 0 \end{cases}$$

ECT_t^+ indicates that the price is too high compared to its long term equilibrium. The opposite holds for ECT_t^-. The resulting asymmetric VECM is:

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$$\Delta \boldsymbol{P}_t^i = a_1 + a_2^+ ECT_{t-1}^+ + a_2^- ECT_{t-1}^- + \sum_{i=1}^{p-1} \boldsymbol{\Gamma}_i \Delta \boldsymbol{P}_{t-i}^j + \Theta \boldsymbol{D}_t + \boldsymbol{\varepsilon}_t, \tag{11}$$

$$\boldsymbol{P}_t^{j \neq i} = [P_t^r \quad P_t^{wd} \quad P_t^{ex} \quad P_t^{im} \quad P_t^p]',$$

In the error correction model, $\boldsymbol{P}_t^i$ denotes the price of the independent variable and $\boldsymbol{P}_t^j$ denotes the price of any of the four remaining prices that can be used to describe $\boldsymbol{P}_t^i$. The cointegration relation is given as: $\boldsymbol{P}_t^i = a_0 + a_1 \boldsymbol{P}_t^j + u_t$. The estimated residuals are lagged by one period and enter the model as the error correct term *ECT* as: $ECT_{t-1} = u_{t-1} = \boldsymbol{P}_t^i - a_0 - a_1 \boldsymbol{P}_t^j$. Two F-tests are performed to infer whether or not there exists price asymmetry in the long term. To verify symmetric price response in the long-term, the F test should reject the null hypothesis of $a_2^- = a_2^+$. If the F-test rejects the null hypothesis of $a_2^- = a_2^+ = 0$, there is significant price adjustment (Wixson and Katchova, 2012).

In the case that the series are found to be *I (0)* as well as the non-stationary price series having unit root but non-cointegrated series ($\boldsymbol{P}_t^i$ and $\boldsymbol{P}_t^j$), the dynamics of the relationship are assessed by means of Autoregressive Distributed Lag (ADL) models. To do so, the Houck (1977) and Ward (1982) approach is followed. This approach basically splits the change in the explanatory variable into positive and negative changes. Goodwin and Holt (1999) and von Cramon-Taubadel (1998), among others, criticize this model for their lack of attention to the time series properties of the data. However, within this study the time series properties of the data are first tested and this model is only used if the prices are stationary and not cointegrated. Following Houck (1977) and Ward (1982), the empirical model used in this chapter for estimating price transmission elasticity and for testing its asymmetry can be expressed as:

$$\boldsymbol{P}_t^{i*} = a_0 + \sum_{j=0}^{k} a_1^+ \Delta \boldsymbol{P}_{t-i}^{j*+} + \sum_{j=0}^{k} a_1^- \Delta \boldsymbol{P}_{t-i}^{j*-} + \boldsymbol{\varepsilon}_t, \tag{12}$$

where the upper script star denotes cumulative values from its starting value $\boldsymbol{P}_0^{i*}$ (i.e. $\boldsymbol{P}_t^i - \boldsymbol{P}_0^{i*}$), and the superscripts + and − denote cumulative values of the rising and falling explanatory price.

$$\sum_{j=0}^{k} a_1^+ \Delta \boldsymbol{P}_{t-i}^{j*+} + \sum_{j=0}^{k} a_1^- \Delta \boldsymbol{P}_{t-i}^{j*-} = \boldsymbol{P}_t^j - \boldsymbol{P}_0^j. \tag{13}$$

The model directly considers the impact of positive and negative variations of $\boldsymbol{P}_t^j$ on $\boldsymbol{P}_t^i$, cumulated from the required lags up to the current period (*i=0*) (Frey and Manera, 2007). It takes into account the distributed lag effect of the cumulative variations (Ward, 1982). A test is performed for Granger Causality within the VAR framework, to assess the direction of price transmission. One F-test is performed to infer whether or not there exists price asymmetry in the short term. In order to verify symmetric price response in the short-term, the F-test is carried out to test if $a_1^- = a_1^+$. The optimal lag length of the ADL model is chosen based on AIC.

4.5 Data

This chapter applies the empirical model outlined in section 3 to two different chains: onions and red peppers. The Netherlands Authority for Consumers and Markets (ACM) provided firm-specific weekly data of producer, wholesale and retail prices. These data are aggregated to weekly prices at each stage of the supply chain. The firm-specific prices are aggregated by multiplying the prices by the market share or firm-weight (for producer prices) of the specific firm to obtain the aggregated wholesale and retail prices. The wholesale price is based on retailers' purchase price. All prices cover the period from January 2005 to December 2008 and are measured in euros per kilogram (see Table 4.1). Marginal costs at the wholesale and retail levels are constant and, thus, captured by the constant term

Table 4.1 Summary Statistics.

Product	Variable[1]	N	Mean (€)	SD	Min	Max
Red Pepper(kg)						
	P^r	208	4.89	0.50	3.64	6.34
	P^{wd}	208	2.48	0.43	1.64	3.85
	P^{ex}	208	1.98	0.36	1.32	2.87
	P^{im}	208	1.33	0.28	0.80	1.95
	P^p	208	1.61	0.69	0.40	4.34
Onions(kg)						
	P^r	208	0.90	0.19	0.47	1.42
	P^{wd}	208	0.46	0.14	0.22	0.91
	P^{ex}	208	0.24	0.08	0.12	0.45
	P^{im}	208	0.32	0.07	0.14	0.49
	P^p	208	0.21	0.12	0.04	0.55

[1] P^r = Retail price; P^{wd} = wholesale price; P^{ex} = export price; P^{im} = import price; P^p = producer price.

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included in the models. Monthly observed import and export data, in both values and quantities, are retrieved from EUROSTAT. Weekly quantities and expenditures are calculated by linear interpolation. Linear interpolation involves estimating a new value by connecting two adjacent known values with a straight line. Subsequently, the prices are determined from the interpolated quantities and expenditures.

The price series comprise 208 weekly observations for each variable per vegetable. Figures 4.1a and 4.1b show the evolution of retail, wholesale, export, import and producer prices for onions and red pepper respectively. Figure 1a indicates a trend in onion prices.

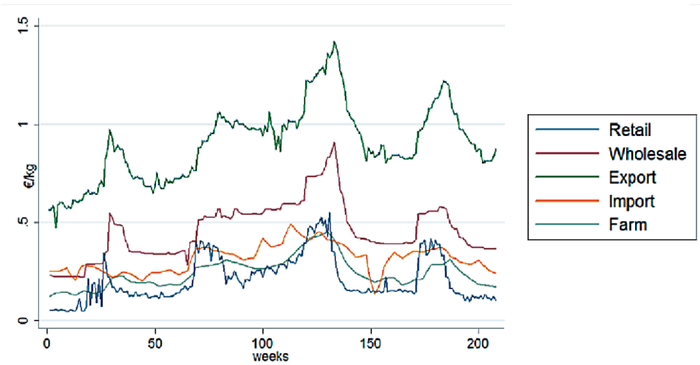

Figure 4.1a Onion prices plot.

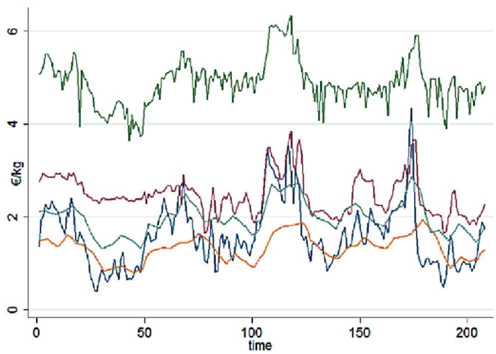

Figure 4.1b Red Pepper prices plot.

4.6 Results

As a first step, the series were examined for the order of integration using the ADF and PP tests. The Appendix (Table 4A) presents both test results with lag length selected using the AIC. The reported statistics show that most variables for red pepper are already stationary in levels at the 1 percent critical level, and only one variable is stationary at the 10 percent critical level according to the ADF test. The onion variables are non-stationary and show also that a trend is present. By taking first-differences and including a trend, the price series of onions are re-tested to determine whether the first-differences of the price series are stationary. The results show clearly that the prices for onions are integrated of order one; *I (1)*.

Before estimating the models, a cointegrating rank test is conducted for onions, as the price series of this product are *I (1)*. The number of cointegration relationships was inferred using the Johansen Trace (ρ_t) and Maximal Eigenvalue test (ζ_t) statistics (Johansen, 1995). The results suggest that four long-term cointegration relationships are present (significant at the 5 percent critical level), in line with the expectations of the theoretical framework developed in this chapter (equations (4'), (6), (7) and (8)). Identification of the cointegration vectors is often done by imposing restrictions on the cointegrating vectors motivated by the theoretical framework. A likelihood ratio test can then be performed to check the validity of those identifying restrictions (Chakraborty and Basu, 2002). The VEC model was fitted as specified in equation (9) to estimate the coefficients of the cointegrating vector of onions. Table 4.2 reports the restrictions imposed on the two cointegrating relationships and the cointegration coefficients (β).

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Table 4.2 Restrictions and coefficients cointegration vector onions.

Cointegration relation (β)[1]	Retail Price	Wholesale Price	Export price	Import price	Producer price	Trend	Constant
1	-0.99** (-16.69)	1	0	0	0	-0.000** (3.34)	0.367
2	0	-0.589** (-17.05)	0	0	1	-0.000 (-0.19)	0.065
3	0	0	1	0	-1	-0.000 (-0.88)	-0.051
4	0	0	0	1	-1	-0.000 (0.26)	-0.112

*denotes 10% significance level

**denotes 5% significance level

[1] LR test of identifying restrictions: chi2(2): 2.679 (p-value 0.262).

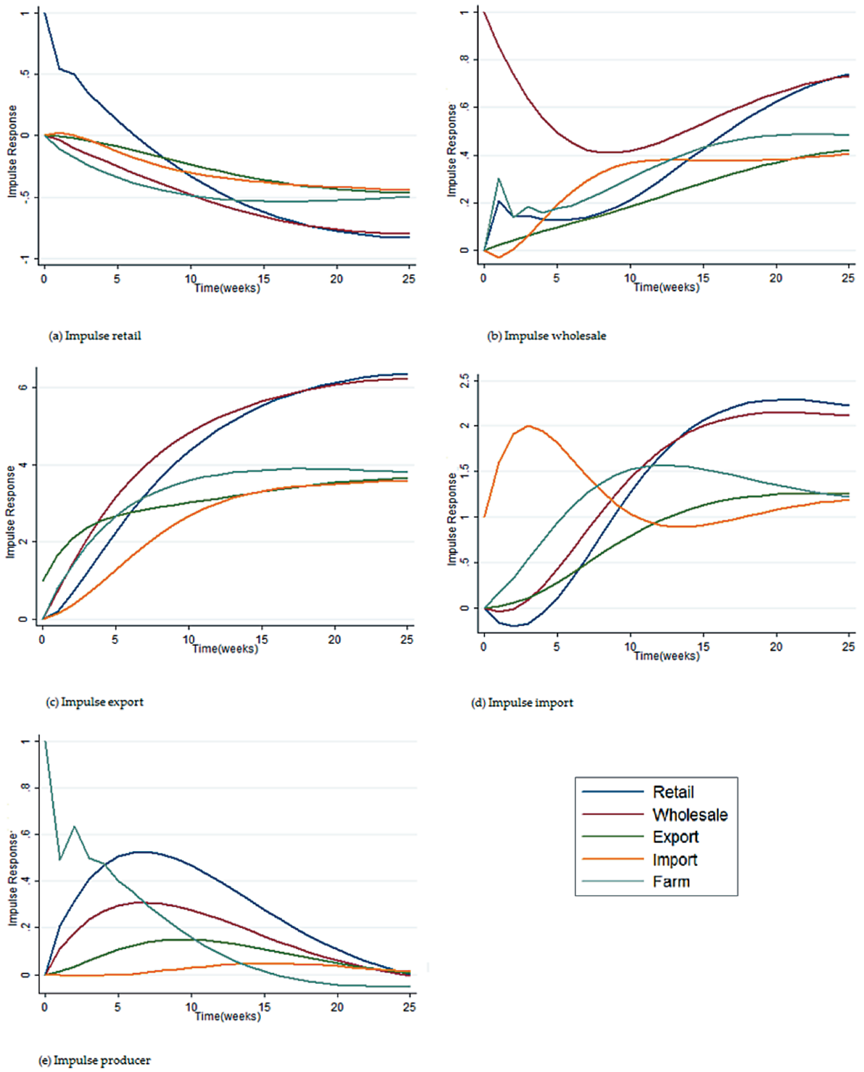
The estimates of Table 4.2 reflect the four equations derived from the theoretical framework. These estimates suggest that the following restricted series for onions are covariance stationary:

(i) $P_t^{wd} = -0.367 + 0.99\, P_t^r - 0.0007\, D_t + \varepsilon_t^1$
(ii) $P_t^p = -0.065 + 0.59\, P_t^{wd} + \varepsilon_t^2$
(iii) $P_t^{ex} = 0.051 + P_{t-1}^p + \varepsilon_t^3$
(iv) $P_t^{im} = 0.112 + P_{t-1}^p + \varepsilon_t^4$

Note that these relations represent only a partial view because price development is also a function of the adjustment coefficients. The first relationship suggests that, in equilibrium, the onion wholesale price equals the onion retail price, a trend and the marginal costs (captured by the constant). The coefficient relating to the onion retail price reflects the possibility of retail oligopoly power, i.e. $0.99 = \left(1 - \frac{\theta^r}{\eta^r}\right)$. This result suggests that retailers are not able to exert market power over consumers (equation (4')), because the conjectural elasticity goes to zero. The second cointegration relation reflects equation (6). The onion producer price equals almost 60 percent of the onion wholesale price, and the difference in marginal costs. This suggests that onion wholesalers are able to exert some market power over retailers, i.e. $0.59 = \left(1 - \frac{\theta^{wd}}{\eta^{wd}}\right)$. The third and fourth relationships suggest that, in equilibrium, the export and import price equal the producer price plus a positive constant, respectively. Table 4.2 does not report the adjustment parameter coefficients. The adjustment parameters results show how quickly prices react to a change in other prices, but the direction of the change (increase or decrease) is unknown.

IRF graphs are used to see the responses of onion prices to shocks in other price shocks. The horizontal axes show the period (weeks) and the vertical axes reflect the price response to a one-unit shock. Figure 3 illustrates impulse responses over the 25 weeks period following a one-unit shock (standard deviation) to prices.

This IRF graph of onions clearly indicates the long-term relationship in the wholesale and international trade prices because after a shock, prices do not return to their former equilibria but show a permanent change. A shock in the wholesale price (graph 4.2b) leads to a permanent increase in all prices, especially in the price of retailers and wholesalers. Retailers and wholesalers instantaneously transmit seventy-five percent of a one-unit shock in the domestic wholesale price, which may indicate market power. Shocks in the export price result in the largest responses of all prices. Retailers and wholesalers fully transmit the shock in the current export price of onions. In the long term, their prices change six-fold relative to their own price level, whereas producer and import prices are quadruple



(a) Impulse retail

(b) Impulse wholesale

(c) Impulse export

(d) Impulse import

(e) Impulse producer

Figure 4.2 Impulse Responses for Onion prices.

after a shock in the export price. The level of export prices affects how wholesalers split the total amount they move into quantities sold domestically and exported, which in turn affects the domestic price that wholesalers can charge. Retailers have to pay this price for avoiding a shortage in their onion supply and transmitting this increase in purchase price to consumers. A shock in the import price of onions leads to a permanent increase in all prices. Dutch wholesalers and retailers are able to increase their onion price twofold, whereas the other prices increase approximately by 100 percent. Both the import and export prices of onions have influence on the prices in the Dutch supply chain. A shock in the producer price of onions leads to a 50 percent (approximately) increase in the retail price and approximately 20-35 percent increase in wholesale and export prices. The responses fade out after 10 weeks. Those responses suggest that wholesalers and retailers easily pass cost or price increases along the chain. The responses found for onions are explained by their specific characteristics. Onions are harvested once per year, stored and gradually sold. Thus, a price shock for these less perishable products has consequences for supply throughout the year. Onions are cultivated in open ground and a shock may easily appear because of, for example, weather conditions or pests.

The perishable vegetable red pepper price series are integrated of order zero. Hence, the coefficients are estimated using the VAR model (equation (10))[3]. The eigenvalue stability of the model is examined and the results suggest stable (eigenvalues less than one) and non-auto-correlated errors. Within the VAR formulation expressed as above, the optimum lag order is selected using the AIC. Using AIC, the lag order four for red pepper has been selected. After fitting the VAR model, the Granger test was applied to determine which of the variables in the system are weakly exogenous. The Granger approach is used to determine how much of the current variable observed can be explained by past values of the same variable and then to determine whether adding lagged values of another variable can improve the explanation[4]. Table 4.3 presents only the Granger causality results that are found to be significant at the 10 percent or 1 percent critical level. The prices throughout the supply chain are either unidirectional (e.g. only from producer to wholesale) or multidirectional (both producer and wholesale prices precede one another). As illustrated in this table, the red pepper producer price precedes all other prices. Equations (7) and (8) from the theoretical framework expect Granger causality relationships between producer prices and export prices and between producer prices and import prices. As shown in Table 4.3, both relationships are bi-directional and significant. Red pepper wholesale prices seem to be a leading indicator of changes in the price of import and export. There is no Granger relationship found in any direction between the red pepper wholesale and retail prices.

3 Due to the space limitation, the full estimation results of the VAR model are not presented.

4 Granger causality measures precedence and indicates the variable that leads and the variable that follows (forecasting ability). It does not imply that one variable is the effect or the result of the other variable (causality).

Table 4.3 Granger Causality Results –Red Pepper

Causality hypothesis	**χ^2- value**		**χ^2- value**
Unidirectional			
P^p *causes* P^{wd}	76.009**		
P^{wd} *causes* P^{ex}	12.903**		
P^{wd} *causes* P^{im}	14.788**		
P^{ex} *causes* P^{im}	52.776**		
Multidirectional			
P^p *causes* P^r	25.462**	P^r *causes* P^p	9.1031*
P^p *causes* P^{ex}	26.558**	P^{ex} *causes* P^p	23.562**
P^p *causes* P^{im}	11.059*	P^{im} *causes* P^p	9.2699*

[1] P^r = Retail price; P^{wd} = wholesale price; P^{ex} = export price; P^{im} = import price; P^p = producer price.
* 10% significant and ** 1% significant

For perishable products, such as red peppers, price shocks are expected to have temporary effects because prices in week *t* depend on supply in week *t* and not on supply in subsequent weeks. This temporary effect is not reflected, except for retail prices, in the IRFs of the prices of red peppers. Figure 4, similar to Figure 3, graphs the responses of the red pepper prices to shocks in its prices. Responses of the prices to an impulse in the red pepper retail price fade out quickly after (approximately) five to ten weeks. Moreover, all red pepper prices barely respond to a shock in the retail price. The shock in the wholesale red pepper price (graph (b)) does have some effect on the other prices. Dutch producers and retailers seem to accommodate a wholesale price shock. The retail price responds by approximately -25 percent after 10 weeks to a shock in the red pepper wholesale price and the impact to the producer price is −50 percent of the wholesale price shock. If retailers have to pay more to wholesalers, they do not transmit this increase to the consumers, suggesting that retailers do not exert retail oligopoly power. Producer prices decrease after a shock in the wholesale prices. Wholesalers, who act together with producers associations, may collect some of these profits and return it to the producers. Red pepper producers and wholesalers act together to serve joint interests. The effects fade out after approximately half a year. A shock in the export price results in increases in all upstream and downstream prices in the first 5

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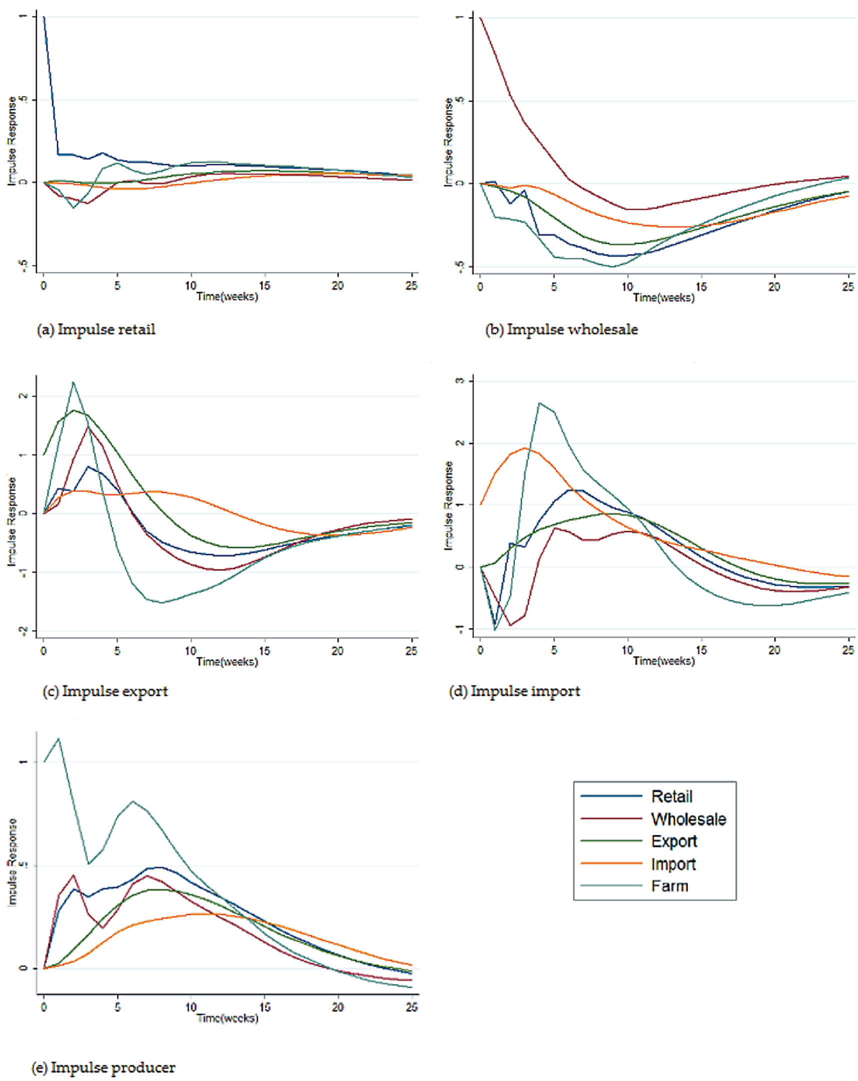

Figure 4.3 Impulse Responses for Red Pepper prices.

weeks. A shock in the import price leads first to a decrease in all prices, but after three weeks the prices follow the increasing trend of the import price. Mainly the producer price follows the development in the import price. A shock at the producer level results in a 50 percent increase in retail and wholesale prices, whereas wholesalers increase the export prices by approximately 40 percent and import prices increase by approximately 25 percent. However, the effects fade out after approximately twenty weeks.

Asymmetric Price Transmission

Since the onion prices were cointegrated, we analysed the asymmetric price transmission using the error correction approach based on equation (11). For this purpose, the residuals of every cointegration relation were divided into negative and positive terms. The results of price asymmetry in onions of equations (4'), (6), (7) and (8) are reported in Table 4.4. The results indicate that asymmetry is present for the pairs of producer price-wholesale price, export price-producer price and import price-producer price. For all three asymmetric price relationships, the

Table 4.4 Estimates of the Error Correction Model for onion prices (standard errors in brackets).

	Equations			
	(4') (P_t^{wd})	(6) (P_t^{p})	(7) (P_t^{ex})	(8) (P_t^{im})
ΔP_{t-1}^{r} [1]	0.038 (0.07)	-0.045 (0.09)	-0.001 (0.00)	0.030 (0.03)
ΔP_{t-1}^{wd}	-0.033 (0.09)	0.254 (0.14)*	0.012 (0.01)	-0.045 (0.03)
ΔP_{t-1}^{ex}	1.140 (0.28)**	0.738 (0.51)	0.647 (0.05)**	0.025 (0.11)
ΔP_{t-1}^{im}	-0.075 (0.15)	0.176(0.23)	0.014(0.02)	0.653(0.05)**
ΔP_{t-1}^{p}	0.075 (0.04)*	-0.325(0.07)**	-0.002(0.00)	0.012 (0.02)
ECT_{t-1}^{+}	0.042 (0.15)	-0.214 (0.07)**	-0.084 (0.02)**	-0.076 (0.02)**
ECT_{t-1}^{-}	0.022 (0.03)	0.106 (0.14)	-0.004 (0.00)	0.006 (0.01)
Constant	0.002	0.008**	0.001**	0.003*
R^2	0.14	0.22	0.74	0.45
Wald Test for Symmetry LR[2]	0.01[~F(1,198)]	3.67*[~F(1,198)]	20.57**[~F(1,198)]	6.91**[~F(1,198)]
Wald Test for Price adjustment LR[2]	0.40[~F(2,198)]	4.65**[~F(2,198)]	16.05**[~F(2,198)]	5.05**[~F(2,198)]
Conclusion	SPT[3]	APT	APT	APT

[1] P^r = Retail price; P^{wd} = wholesale price; P^{ex} = export price; P^{im} = import price; P^p = producer price.
[2] A F-test of the null hypothesis of symmetry in the long term: $a_2^+ = a_2^-$ A F-test of the null hypothesis of price adjustment in the long term: $a_2^+ = a_2^- = 0$.
[3] SPT= symmetric price transmission; APT= asymmetric price transmission
* and ** denote significance ate 10% and 1% levels respectively.

4

positive error correction term (ECT^{+}_{t-1}) is significant and higher (in absolute terms) than the negative error correction term (ECT^{-}_{t-1}), which means that the adjustment in response to deviations from the equilibrium is faster when the deviation is positive (e.g. when the export onion price is higher than the domestic onion producer price) than when it is negative. More specifically, if the export onion price is above its equilibrium with respect to the producer price of onions, the export price will decrease with 8.5 percent during the following week. Asymmetry between onion producers and onion wholesalers may be caused due to storage possibilities. If the producer price of onions is above its equilibrium the producer price will decrease by 21 percent the following week.

These results may have implications for the different stages involved in the onion supply chain. Onion producers and wholesalers can use this information to determine their purchase and sales strategy based on the price relationships. For example, if an onion wholesaler notices that the export price for onions is higher than expected in relation to the producer price, the wholesaler may decide to use a forward contract with the exporters to avoid lower export prices in the following weeks.

Table 4.5 presents the results of the test of asymmetry in price transmission relationships using the Houck and Ward approach for stationary price series. The

Table 4.5 Estimates of the Houck Model for red pepper prices (standard errors in brackets).

	Equations			
	$P^p_t \rightarrow P^r_t$	(6) (P^p_t)	(7) (P^{ex}_t)	(8) (P^{im}_t)
ΔP^{j+}_t	1.618 (0.25)**	1.854 (0.27)**	0.068 (0.05)	-0.002(0.06)
ΔP^{j-}_t	0.570 (0.12)**	1.373 (0.23)**	0.035 (0.12)	-0.020 (0.13)
ΔP^{j+}_{t-1}	-0.458 (0.25)*	-0.476 (0.51)*	0.332 (0.05)**	0.208 (0.06)**
ΔP^{j-}_{t-1}	0.379 (0.12)**	-0.363(0.23)	0.480(0.12)**	0.402(0.05)**
Constant	0.405**	0.534**	-0.229**	-0.172**
R^2	0.55	0.56	0.68	0.40
$a^{+}_{1t} = a^{-}_{1t}$	12.39** [~F(1,202)]	1.63[~F(1,202)]	0.06[~F(1,202)]	0.01[~F(1,202)]
$a^{+}_{1t-1} = a^{-}_{1t-1}$	7.98** [~F(1,202)]	0.09[~F(1,202)]	1.18[~F(1,202)]	1.76[~F(1,202)]
Conclusion	APT[2]	SPT	SPT	SPT

[1] P^r = Retail price; P^{wd} = wholesale price; P^{ex} = export price; P^{im} = import price; P^p = producer price.
[2] SPT= symmetric price transmission; APT= asymmetric price transmission
* and **denote significance ate 10% and 1% levels respectively.

number of lags is chosen via the AIC criterion and for all relations, estimated using an ADL (1,1) model (using one extra 1 lag). For the theoretical equations (6, 7 and 8), price transmission was found to be symmetric in the short term (Table 4.5). For the relationship between wholesalers and retailers (4'), the causality of both directions is rejected, implying that the direction of price causality is inconclusive. This invalidates the specification of either the VAR equation and any statistical results obtained from the asymmetric regression cannot be valid. However, an asymmetric price transmission relationship was observed for red pepper producer prices and retail prices. This means that the producer price of red pepper adjusts more rapidly upward when retail prices are higher, and adjust slower to retail price decreases.

4.7 Policy Implications

The analysis of vertical price transmission can give insights into the development and interrelationships of prices throughout the chain. The behaviour of each stage in the chain in the short- and long-term is examined. Existence of asymmetric price adjustments could imply a number of different things about the market, such as different menu costs, storability or the exercise of market power. A possible implication of asymmetric price transmission is that consumers are not benefiting from a price reduction at the producer level, or producers might not benefit from a price increase at the retail level.

From the results of this study, it seems that the product characteristics of onions and red peppers primarily explain the differences in the evidence for asymmetric price transmission. In the onion chain, market stages have interrelationships in the long term. Onions are non-perishable and easier to store. Although the results from this chapter found evidence for wholesale oligopoly power in the onion sector, no evidence for asymmetric price adjustment has been found. Asymmetric price adjustment has been found between the prices of onion producers and wholesalers, between import prices and producer prices and between export prices and producer prices. The price relations between the international prices (i.e. import and export) and the domestic producer price of onions is consistent, since the Netherlands is a big importer and exporter of onions. Outliers in selling and buying quantities in one week may give a reflection of different price regimes in onions.

The price relationships between the different stages in the red pepper chain are in the short term. Greenhouse red peppers are highly perishable and the actors in the different stages have to respond faster. In the red pepper chain, asymmetric price adjustment has been found been between red pepper producers and retailers. Red pepper producers adjust their prices upwards faster to retail price increases, than they adjust them downwards to retail price decreases. This study did not examine the possible market power of red pepper producers, so the reason of the short-term asymmetric price adjustment between the producers and retailers is not determined.

4.8 Conclusions

This chapter analysed the vertical asymmetric price transmission in the Dutch food supply chains for onions and red peppers. A theoretical model of firm behaviour was developed that linked prices throughout the chain, including market power at the wholesale and retail levels. Weekly data on the two supply chains during the period 2005–2008 using VEC and VAR models and ECM and Houck models to test for asymmetry, were applied to the theoretical framework.
The empirical results indicate that long-term relationships and asymmetry exist in the onion market. However, there is no evidence for market power of retailers to consumers. The cointegration relations suggest market power from wholesalers to retailers. The production characteristics of onions (limited perishability, harvested once per year) versus red peppers (high perishability, harvested throughout the year) may give wholesalers the ability to exert market power. Onion wholesalers can use storage to control supply due to the strong bargaining position or due to scarcity caused by a bad harvest. Wholesale prices remain high after a one-time shock. The results suggest that shocks in wholesale and export prices affect consumers' welfare: retail prices increase permanently. A change in export prices affects the quantity that wholesalers sell on the domestic market and, thus, domestic wholesale prices. Retailers respond and transmit the increase in wholesale prices to consumers. The empirical results suggest that asymmetric price changes do occur in the Dutch onion market. Asymmetric price adjustment has been found between the prices of onion producers and wholesalers, between import prices and producer prices and between export prices and producer prices. All of these asymmetric adjustments respond to deviations from the equilibrium faster when the deviation is positive (e.g. when the export onion price is higher than the domestic onion producer price) than when it is negative.

For the red peppers chain, price shocks along the entire supply chain fade out and prices quickly return to their original equilibria after 20 weeks. This situation also holds for wholesalers. The responses to price shocks at the wholesale level fade out after approximately 10 weeks, even though red pepper wholesalers constituted a cartel from May 2006 until February 2009. Asymmetry in the short-term is only visible between producer and retail red pepper prices. In the Dutch red pepper chain, wholesalers represent producer's interest, and it may be the case that producers were able to asymmetrically adjust their prices to retailers in the cartel case. Red pepper producers adjust in the short-term their prices more rapidly upward when retail prices are higher, and adjust slower to retail prices decreases. Moreover, domestic red pepper prices along the chain respond to a one-time shock in export prices. Pepper export prices are determined in the world (European) markets and influence domestic supply chain prices, but are also preceded by the domestic producer prices. Red pepper is also an important export commodity of the Netherlands.

In contrast to expectations of policy-makers and producers in the agro-food chain, no evidence exists of the market power of retailers in the chains of both vegetables. However, the results suggest wholesaler market power in the supply chain of onions. Onion wholesalers act as a price leader in wholesale-retail market of onions. On the other hand, there is no evidence found for market power between wholesalers and retailers in the red pepper chain. The difference is attributed to the characteristics of the products, such as perishability and the length of the harvest period.

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References

Appelbaum, E. 1982. The estimation of the degree of oligopoly power. *Journal of Econometrics* 19: 287-299.

Azzam, A.M. 1997. Measuring market power and cost-efficiency effects of industrial concentration. *Journal of Industrial Economics* 45: 377-386.

Azzam, A.M. and Pagoulatos, E. 1990. Testing oligopolistic behaviour: an application to the US meat-packing industry. *Journal of Agricultural Economics* 41: 362-370.

Borenstein, S., Cameron, A.C. and Gilbert, R. 1997. Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes? *The Quarterly Journal of Economics* 112: 305-339.

Bresnahan, T.F. 1982. The Oligopoly solution concept is identified. *Economics Letters* 10: 87-92.

Brester, G.W. and Goodwin, B.K. 1993. Vertical and Horizontal Price Linkages and Market Concentration in the U.S. Wheat Milling Industry. *Review of Agricultural Economics* 15: 507-519.

Bunte, F. 2009. Prijsvorming glastuinbouw. Nota 09-02.Den Haag: Agricultural Economics Research Insitute (LEI).

Carter, C.A. and MacLaren, D. 1997. Price or Quantity Competition? Oligopolistic Structures in International Commodity Markets. *Review of International Economics* 5: 373-385.

Chakraborty, C. and Basu, P. 2002. Foreign direct investment and growth in India: a cointegration approach. *Applied Economics* 34: 1061-1073.

DeeVon, B. and Brorsen, B.W. 1989. Price Asymmetry in Spatial Fed Cattle Markets. *Western Journal of Agricultural Economics* 14: 246-252.

Digal, L.N. 2010. Market Power Analysis: The Case of Poultry Industry in the Philippines. *Journal of International Food & Agribusiness Marketing* 23: 5-31.

Enders, W. 2004. *Applied Econometric Time Series*. New York: John Wiley & Sons, Inc.

Engle, R.F. and Granger, C.W.J. 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica* 55: 251-276.

Frey, G. and Manera, M. 2007. Econometric models of asymmetric price transmission. *Journal of Economic Surveys* 21: 349-415.

Gardner, B.L. 1975. The Farm-Retail Price Spread in a Competitive Food Industry. *American Journal of Agricultural Economics* 57: 399-409.

Goetz, L., von Cramon-Taubadel, S. and Kachel, Y. 2008. Measuring Price Transmission in the International Fresh Fruit and Vegetable Supply Chain: The Case of Israeli Grapefruit Exports to the EU. Discussion Paper 10.08.

Goodwin, B.K. 2006. Spatial and Vertical Price Transmission in Meat Markets. Paper presented at: Market Integration and Vertical and Spatial Price Transmission in Agricultural Markets Workshop, University of Kentucky, April 21.

Goodwin, B.K. and Holt, M.T. 1999. Price Transmission and Asymmetric Adjustment in the U.S. Beef Sector. *American Journal of Agricultural Economics* 81: 630-637.

Granger, C.W.J. and Newbold, P. 1974. Spurious regressions in econometrics. *Journal of Econometrics* 2: 111-120.

Hamilton, J.D. 1994. *Time Series Analysis*: Princeton University Press.

Hassouneh, I., von Cramon-Taubadel, S., Serra, T. and Gil, J.M. 2012. Recent developments in the Econometric Analysis of Price transmission. Grant Agreement No. KBBE-265601-4-TRANSFOP. Transparency of Food Pricing (TRANSFOP).

Houck, J.P. 1977. An Approach to Specifying and Estimating Nonreversible Functions. *American Journal of Agricultural Economics* 59: 570-572.

Huang, S.-Y. and Sexton, R.J. 1996. Measuring Returns to an Innovation in an Imperfectly Competitive Market: Application to Mechanical Harvesting of Processing Tomatoes in Taiwan. *American Journal of Agricultural Economics* 78: 558-571.

Jacquemin, A., Ghellinck, E.d. and Huveneers, C. 1980. Concentration and Profitability in a Small Open Economy. *The Journal of Industrial Economics* 29: 131-144.

Johansen, S. 1995. *Likelihood-based inference in cointegrated vector autoregressive models*. Oxford [etc.]: Oxford University Press.

Johansen, S.r. and Juselius, K. 1992. Testing structural hypotheses in a multivariate cointegration analysis of the PPP and the UIP for UK. *Journal of Econometrics* 53: 211-244.

Koop, G., Pesaran, M.H. and Potter, S.M. 1996. Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics* 74: 119-147.

Kuiper, E., Lutz, C. and van Tilburg, A. 2003. Vertical price leadership on local maize markets in Benin. *Journal of Development Economics* 71: 417-433.

Kuiper, W.E. and Meulenberg, M.T.G. 2002. Vertical price leadership: A cointegration analysis. *Agribusiness* 18: 317-331.

Lloyd, T.A., McCorriston, S., Morgan, C.W. and Rayner, A.J. 2001. The impact of food scares on price adjustment in the UK beef market. *Agricultural Economics* 25: 347-357.

Lloyd, T.A., McCorriston, S., Morgan, C.W. and Rayner, A.J. 2006. Food scares, market power and price transmission: the UK BSE crisis. *European Review of Agricultural Economics* 33: 119-147.

Lütkepohl, H. 2005. *New Introduction to Multiple Time Series Analysis*. Berlin Heidelberg: Springer-Verlag GmbH.

Lütkepohl, H. and Reimers, H.-E. 1992. Impulse response analysis of cointegrated systems. *Journal of Economic Dynamics and Control* 16: 53-78.

McCorriston, S., Morgan, C.W. and Rayner, A.J. 1998. Processing Technology, Market Power and Price Transmission. *Journal of Agricultural Economics* 49: 185-201.

McCorriston, S., Morgan, W. and Rayner, J. 2001. Price transmission, market power, marketing chain, returns to scale, food industry. *European Review of Agricultural Economics* 28: 143-159.

Meyer, J. and von Cramon-Taubadel, S. 2004. Asymmetric Price Transmission: A Survey. *Journal of Agricultural Economics* 55: 581-611.

NMa. 2009. Prijsvorming in de agri-food sector.The Hague: Nederlandse Mededingingsautoriteit (NMa).

NMa. 2013. NMa beboet uienhandel. Available at: "http://www.nma.nl/documenten_en_publicaties/archiefpagina_nieuwsberichten/nieuwsberichten/2013/03_13_nma_beboet_uienhandelaren_voor_kartel.aspx" (last accessed 5th March 2013).

NOS. 2012. Kartelboete paprika- en uientelers. Available at: "http://nos.nl/artikel/380362-kartelboete-paprika-en-uientelers.html" (last accessed 15 June 2012).

Peltzman, S. 2000. Prices Rise Faster than They Fall. *Journal of Political Economy* 108: 466-502.

Serra, T. and Goodwin, B.K. 2003. Price transmission and asymmetric adjustment in the Spanish dairy sector. *Applied Economics* 35: 1889-1899.

Sexton, R.J., Sheldon, I., McCorriston, S. and Wang, H. 2007. Agricultural trade liberalization and economic development: the role of downstream market power. *Agricultural Economics* 36: 253-270.

Sexton, R.J. and Zhang, M. 2001. An assessment of the impact of food industry market power on U.S. consumers. *Agribusiness* 17: 59-79.

Soregaroli, C., Sckokai, P. and Moro, D. 2011. Agricultural policy modelling under imperfect competition. *Journal of Policy Modeling* 33: 195-212.

von Cramon-Taubadel, S. 1998. Estimating asymmetric price transmission with the error correction representation: An application to the German pork market. *European Review of Agricultural Economics* 25: 1-18.

Wann, J.J. and Sexton, R.J. 1992. Imperfect Competition in Multiproduct Food Industries with Application to Pear Processing. *American Journal of Agricultural Economics* 74: 980-990.

Ward, R.W. 1982. Asymmetry in Retail, Wholesale, and Shipping Point Pricing for Fresh Vegetables. *American Journal of Agricultural Economics* 64: 205-212.

Wixson, S.E. and Katchova, A.L. 2012. Price Asymmetric Relationships in Commodity and Energy markets. Paper presented at: 123rd EAAE Seminar Dublin, Ireland, February 23-24.

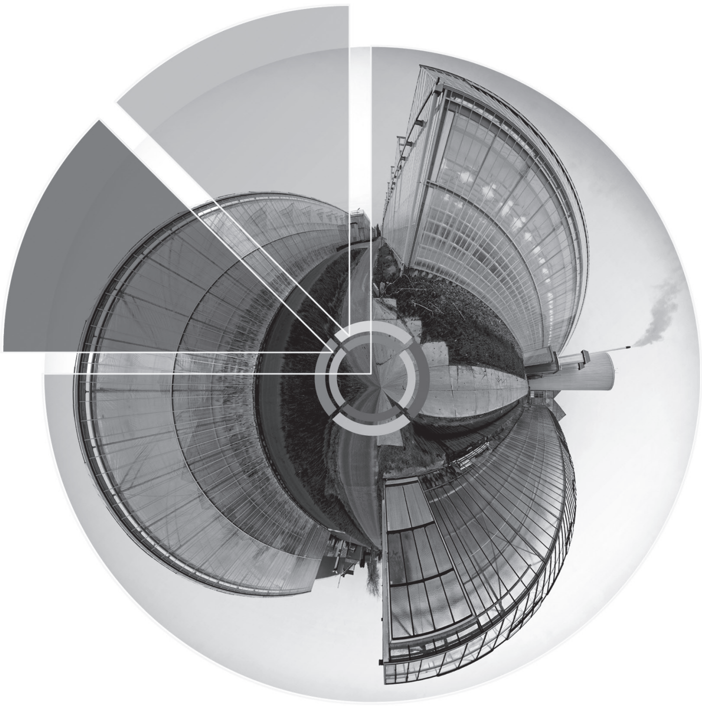
Wolffram, R. 1971. Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches: Some Critical Notes. *American Journal of Agricultural Economics* 53: 356-359.

Appendix 4A

Table 4A Unit Root Results

Product	Variable[1]		Constant	Lags[2]	Trend	Lags	First Difference[3]	Lags
Red Pepper(kg)								
	P^r	ADF	-2.578*	3	-2.777	3	n.a	
		PP	-4.373**		-4.733**			
	P^{wd}	ADF	-3.496**	3	-3.587**	3	n.a	
		PP	-3.830**		-3.948**			
	P^{ex}	ADF	-4.413**	2	-4.500**	1	n.a	
		PP	-4.083**		-4.073**			
	P^{im}	ADF	-4.951**	4	-4.320**	1	n.a	
		PP	-3.743**		-3.665**			
	P^p	ADF	-2.928**	6	-3.372*	4	n.a	
		PP	-3.468**		-4.491**			
Onions(kg)								
	P^r	ADF	-2.653*	2	-1.948	2	-3.291*	10
		PP	-2.091		-1.737		-15.171**	
	P^{wd}	ADF	-2.373	3	-1.921	2	-5.484**	3
		PP	-2.017		-1.601		-12.711**	
	P^{ex}	ADF	-3.060	2	-2.687	1	-4.509**	1
		PP	-2.380		-2.067		-5.887**	
	P^{im}	ADF	-2.938**	1	-2.564	2	-3.223**	6
		PP	-3.551**		-3.518		-11.874**	
	P^p	ADF	-2.650*	2	-2.018	1	-10.584**	1
		PP	-2.814*		-2.521		-21.009**	

[1] P^r = Retail price; P^{wd} = wholesale price; P^{ex} = export price; P^{im} = import price; P^p = producer price. The unit root test results for the export and import prices are based on the original monthly data.
[2] Number of lags specified per variable via the Akaike Information Criterion (AIC).
[3] n.a. = not applicable; onion variables are first-differenced including trend;
* 10% significant and ** 1% significant



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Dynamic and static behaviour with respect to energy use and investment of Dutch greenhouse firms

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Abstract

Dutch greenhouse horticulture firms are energy-intensive and major emitters of greenhouse gases. This chapter develops a theoretically consistent model that is able to describe the greenhouse firms' behaviour regarding energy use and investments in energy technology. The behaviour of the firm is modelled using a combination of a dynamic cost function and a static profit function framework. The optimal quantity of energy is derived from the link between these two functions. The model is applied to a panel of 97 Dutch greenhouse firms over the period 2001-2008. The results show that most Dutch greenhouse firms shift from being net electricity users to net electricity producers in the long term. Investing in energy capital contributes to reducing net energy use, however it increases the quantity of carbon dioxide emissions due to an increase in electricity production. A 1 % increase of the price of gas reduces carbon dioxide emissions by 1.6 %.

Keywords: Adjustment costs; Dynamic duality; Energy; Greenhouse horticulture; Short-term marginal cost

5.1 Introduction

The increasing focus of European governments on climate change and sustainability has led to a range of policies and covenants in the agricultural sector. Most policies and covenants focus on reducing emissions of greenhouse gases (GHGs) and sustainability issues. Greenhouse horticulture production is the most energy-intensive agricultural sector in the Netherlands and a major contributor to carbon dioxide (CO_2) emissions. The greenhouse sector accounts for approximately 9 percent of the total natural gas use and for 4.5 percent of total CO_2 emissions in the Netherlands. Additionally, the horticulture sector's dependence on energy makes the profitability of the firms vulnerable to energy price increases. Dutch greenhouse production relies heavily on the use of natural gas.

The Dutch greenhouse horticulture sector and the Dutch government share a keen interest in reducing fossil fuel use and CO_2 emissions. Because of its size and intensity of energy use, the government provided the sector subsidies and tax incentives to encourage greenhouse firms to invest in energy-saving equipment. The sector has made agreements with the Dutch government in which objectives for energy saving and the production of sustainable energy have been set (the so-called Clean and Efficient Agri Sectors Agreement). The two parties agreed upon targets for 2020, such as a forty-five percent reduction of the total CO_2 emissions compared to 1990, an improvement of energy efficiency by 2 percent per year on average and a twenty percent share of sustainable energy (Ministerie van Landbouw Natuur en Voedselkwaliteit, 2008).

At the same time, the Dutch greenhouse sector is a major electricity producer. Since 2006, the sector is a net supplier of electricity. Electricity is produced with combined heat and power equipment (CHP). This technology enables greenhouse producers to exploit economies of scope in producing electricity, heating and CO_2. The released heat from electricity production is now utilised, unlike general power plants where more than half of fuel consumption is lost as waste. Both heat and CO_2 are essential inputs in greenhouse horticulture. CO_2 is used as an input to accelerate plant growth and the heat generated is used for heating the greenhouse. The surplus of electricity is sold to the national grid. CHPs have an important influence on controlling the energy costs of greenhouse horticulture firms. The strong growth of CHPs in 2000-2008 lead to more natural gas consumption by the sector, an increase in CO_2 emissions, lower purchases of electricity and higher sales. However, from 2010 onwards, the demand of CHPs in the Dutch greenhouse horticulture has stagnated. Lower subsidies by the Dutch government and stabilization of energy prices resulted in narrower margins for CHPs than in the past (Energy Matters, 2011).

Besides the use of CHPs, the Dutch greenhouse sector adheres to a CO_2 sector system, restricting the quantity of CO_2 emissions per firm. The sector has made a new agreement with the Dutch government that CO_2 emissions of greenhouse horticulture will decrease by more than twenty percent (Product Board Horticulture, 2012). The CO_2 sector system is compulsory for all Dutch greenhouse horticulture firms, except for the firms which have already joined the European Emission Trade System (ETS). The standard of the CO2-sector system is that the participating firms must meet a jointly agreed emission target for CO_2 emissions of greenhouse horticulture. This emission target is allocated among individual firms. The individual values are reduced by three percent every year. If an individual firm achieves further reductions, then it is rewarded financially. If the sum of the individual firms exceeds the fixed emission target, the participating firms have to pay. In return for applying the CO_2 sector system, the European Commission agrees with the reduced energy tax for the Dutch greenhouse horticulture sector. Additionally, a wide range of other energy-saving technologies are used in the Dutch greenhouse horticulture industry to reduce energy consumption, such as climate computers, condensers, and heat buffers.

The developments and policy reforms in the sector imply that energy use by horticulture firms can be reduced by enhancing factor substitution between variable inputs and abatement activities. Both require an understanding of the interrelationships among inputs and the use of capital (Syed, 2011). Greenhouse firms can switch to inputs that use energy resources less intensively. Abatement activities imply demand for intermediate goods, capital and labour and the accumulation of a stock of abatement capital. As a result, the interaction between capital and energy use indicates that energy use efficiency may be increased by new technological possibilities and opportunities for the firms and, hence by increasing their use of capital. Investment choices of greenhouse producers represent long-term commitments and can be seen as a solution to dynamic optimization problems (Pietola and Lansink, 2006). The static optimization framework is, therefore, inappropriate for examining the structure of production and investment in the greenhouse sector.

Many studies on energy demand have been based on a static system of factor demand equations which assumes that producers adjust instantaneously to changes in the market and the technological environment in which they operate (Asche *et al.*, 2008). Although this assumption simplifies the analysis, it is well known that producers do not react instantaneously to changes in prices and other exogenous factors (Epstein, 1981). The dual approach has been widely employed for examining dynamic adjustment in agriculture (Epstein and Denny, 1983; Vasavada and Chambers, 1986; Howard and Shumway, 1988; Vasavada and Ball, 1988; Weersink, 1990; Fernandez-Cornejo *et al.*, 1992; Stefanou *et al.*, 1992; Agbola, 2005;

Serra *et al.*, 2010). Economic impacts of measures aiming at reducing CO_2 emissions and energy use in the greenhouse sector have been analysed by Oude Lansink and Van der Vlist (2008), Oude Lansink (2003), and Pietola and Oude Lansink (2006). None of them, however, used the dynamic approach in their analysis.

The aim of the present chapter is to develop a theoretically consistent model that is able to describe the greenhouse firms' behaviour regarding energy use/electricity production and investments in energy related equipment. The behaviour of the firm with respect to the optimal use of energy is modelled using a combination of a dynamic cost minimization and a profit maximization framework. This two-stage approach enables us to stress the dynamic relations between energy capital accumulation and electricity production. The dynamic model of adjustment of the energy capital stock is used to determine the optimal quantities of gas, electricity and an aggregated group of other energy, both in the short- and the long-term, and can be used for long-term predictions. The possibility of using specialized equipment to produce electricity that is sold to the grid is also taken into account. Firms are assumed to maximize short-term profit given the quantities of quasi-fixed factors and an energy use level. Next, the short-term marginal cost of the dynamic cost function is linked in an innovative way with the shadow price of energy of the static profit function. The optimal quantity of energy is derived from this link between the two functions.

This chapter contributes to the agricultural and energy economics literature in the following ways: first, the firm's behaviour is modelled in two stages, namely a static profit maximization and a dynamic cost minimization framework. Second, a detailed analysis of demand for different energy inputs is conducted using the second stage dynamic cost function. A novelty of our research is that we explicitly link the static and dynamic frameworks and derive the optimal quantities of energy capital and energy. Therefore, the model can generate a number of policy insights into firm behaviour with respect to energy use, investment and reducing CO_2 emissions that are useful for the design of future energy or emission reducing policies.

The structure of the remainder of this chapter is as follows. Section 2 develops the theoretical model of firm behaviour which is separated into two parts: static profit maximization behaviour and dynamic cost minimization behaviour. The two parts are connected in the third sub-section. Section 3 specifies the empirical model. Section 4 describes the data sources and estimation method. The results are presented in section 5 and implications of simulations regarding the current regime, are given in section 6. The results and implications are discussed in section 7.

5.2 Theoretical Model

In this chapter, we aim to model firm behaviour regarding outputs and inputs and analyse investments in energy inputs. Although, it is possible to specify a single dynamic profit function that includes all variables in one function, we choose to use a two-stage approach in which we distinguish a static profit function and a dynamic cost function. There are several reasons for applying a two-stage approach. Firstly, this approach is applied to focus on and stress the separate energy components in the Dutch greenhouse horticulture sector. Secondly, including all variables in one dynamic profit function would result in a model with a very large number of variables, which would greatly complicate the estimation and would most likely fail to satisfy regularity conditions. However, we attempted to estimate a dynamic profit function, including all variables. Different versions and instruments were tried, but the model provided unreliable results, neither did the model converge. Lastly, the two stage approach can stress the importance of energy costs and to incorporate adjustment costs for energy-saving equipment only. Our two-stage approach uses first-order conditions for profit maximization to link the dynamic and static components and enables us to estimate the optimal quantity of energy needed in the Dutch greenhouse horticulture sector.

Profit maximization function

We assume that the objective of a greenhouse producer is to maximise profits. Producers maximise profit given the level of output and input prices and quantities of quasi-fixed inputs. At this stage, firms take energy input as given. This means that firms are assumed to be maximizing profit conditional upon the amount of energy-use. The restricted profit function for a multi-output production technology is obtained as:

$$\Pi(P(t);Z(t),\bar{E}) = \max_{(Y,Z)\in T(E)} \sum_{j=1}^{M} P_j Y_j \tag{1}$$

This is under the restriction that the quasi-fixed factors (Z), the quantity of energy use (E) and netputs (Y) are feasible, given the production technology.

This modelling framework assumes weak separability between energy netputs and the variable inputs. It implies that the marginal rate of substitution between energy netputs is independent of the quantity of other inputs and outputs (Chambers, 1988). Furthermore, we presume that the capital input is irrelevant to the energy quantity variation in the short term. Thus, capital other than energy-producing or energy-using is not a function of energy. The profit function is assumed to be linearly homogeneous and convex in *P*, concave and increasing in *Z* and non-negative. Netput supply functions are derived using Hotelling's lemma:

$$Q_i^*(P(t);Z(t),\bar{E}) = \frac{d\Pi(P(t);Z(t),\bar{E})}{dP}, \tag{2}$$

where Q_i^* is the variable netput vector, positive for outputs and negative for variable inputs.

Dynamic cost minimization function

At time *t*, the firm's dynamic production plan involves minimizing the discounted sum of future energy costs over an infinite horizon, producing at least energy output level, E. This gives us the value function as a solution to the problem:

$$J(w,rc,E,K,t) = \min_{(I>0)\in t} \int_0^\infty e^{-it}[C(w,E(t),K(t),I(t),t) + rc' K]dt, \tag{3}$$

s.t.

$$\dot{K}(t) = I(t) - \delta K_t,$$

$$K(t) > 0 \quad \text{for all t},$$

$$E(t) = F(X(t),K(t),\dot{K}(t),t),$$

where *K* is the stock of energy capital, related to energy equipment. This energy capital quantity includes machinery, installations and equipment related to energy (e.g. temperature screens, CHPs). *X* is a vector of the inputs consisting of electricity, gas, and other energy, at prices *w*; *I* is the gross rate of investment in the quasi-fixed input; *rc* is the rental rate of capital, *i* is a (constant) real discount rate; and δ is the rate of depreciation of the quasi-fixed energy capital. $\dot{K}$ is the net investment of energy capital and *F* is a production function describing the transformation of energy inputs into energy output (*E*) and meets the usual regularity conditions (Epstein and Denny, 1983).

The value function is assumed to be non-negative, twice continuously differentiable, non-decreasing in *w* and *rc*, decreasing in *K*, and concave in *w* (when positive input) and *rc*. Under these conditions, the Hamilton-Jacobi-Bellman (HJB) equation is:

$$
\begin{aligned}
& iJ(w,rc,E,K,t) \\
&= \min_{(I>0)\in t} \Big\{ \big[C(w,E(t),K(t),I(t),t) + rc^{'}K \big] + J_k(I(t) - \partial K_{t-1}) \\
&+ \varphi \Big(E - F(X(t),K(t),\dot{K}(t),t) \Big) \Big\} + J_t,
\end{aligned} \tag{4}
$$

where φ is the Lagrange multiplier associated with the energy production target. The Lagrange multiplier can be used to estimate the shadow price of an extra unit of energy output in the short term, by formulating the optimization problem as a sequential decision (see Stefanou (1989)). The HJB is interpreted as the sum of netput costs, rental costs, adjustment costs and the shadow price associated with the amount of energy production. J_k is the shadow price of energy capital, i.e. dJ/dK It is negative if the firm is undercapitalized, while it is optimal to decrease the capital stock size (i.e. the firm is overcapitalized) when the shadow value of capital is positive (Stefanou, 1989). Netput demand equations are obtained using Shephard's Lemma. The conditional demands for the variable netputs and the net investment demand equation are:

$$X^{*} = iJ_w(w,rc,E,K,t) - J_{wK}(w,rc,E,K,t)\dot{K} - J_{wt}(w,rc,E,K,t) \tag{5}$$

$$\dot{K}^{*} = J_{rK}^{-1}(w,rc,E,K,t)\left[iJ_{rc}(w,rc,E,K,t) - K - J_{rct}(w,rc,E,K,t)\right] \tag{6}$$

It will be assumed that C satisfies all regularity conditions (Epstein and Denny, 1983).

Connection of the two functions

Economic theory requires the restricted profit function (1) to be convex in prices and increasing and concave in quasi-fixed factors. In our case, energy output is a quasi-fixed factor in the restricted profit function. If the restricted profit function is well defined and satisfies the usual regularity conditions, the first-order condition for profit maximization with respect to energy is:

$$\frac{d\Pi}{dE} = s_E \geq 0 \quad , \tag{7}$$

which states that the shadow-price of energy is equal to the first derivative for the profit function with respect to energy. The short-term marginal cost of energy output,, is given by:

$$C_{E(t)} = iJ_{E(t)} - \dot{K}J_{KE} - J_{tE}. \tag{8}$$

The short-term marginal cost of energy can be seen as the shadow cost of this input. The relation between the restricted profit function and the cost function can be derived from the theoretical properties of the two functions, i.e. $\frac{d^2\Pi}{dE^2} < 0$, and $\frac{d^2C}{dE^2} > 0$. These conditions guarantee that there exists a point of equilibrium. At the optimum, the shadow price for energy is equal to the marginal cost of production.

$$\frac{d\Pi}{dE} = s_E = C_{E(t)}\,. \tag{9}$$

This means that the optimal quantity of energy is a function of energy capital, adjustment costs, energy inputs, and of the variables within the profit function.

5.3 Empirical specification

For the empirical application, the profit and cost functions are specified as Normalized Quadratic (Epstein, 1981; Vasavada and Chambers, 1986). The Normalized Quadratic (NQ) function is a flexible functional form and has been widely applied in agricultural economics for modelling static and dynamic multi-output production, profit and cost functions. The NQ function is chosen because it leads to supply and input demand equations from the profit function and input and investment demand equations from the cost function that are linear in normalized prices, global curvature properties can be assessed and it facilitates the connection of the two functions. With the NQ function, one input is used as the numéraire. The normalized quadratic restricted profit function for any firm f is given by:

$$\begin{aligned}\Pi_f^* = {} & a_0 + a_1 p_{1f}^* + a_2 p_{2f}^* + a_{12} p_{1f}^* p_{2f}^* + \frac{1}{2}\left(a_{11} p_{1f}^* p_{1f}^* + a_{22} p_{2f}^* p_{2f}^*\right) + \sum_{k=1}^{4} \beta_k Z_{kf} \\ & + \frac{1}{2}\sum_{k=1}^{4}\sum_{k=1}^{4} \beta_k Z_{kf}\, \beta_k Z_{kp} + \sum_{n=1}^{4} \gamma_{1k} p_{1f}^* Z_{kf} + \sum_{n=1}^{4} \gamma_{2k} p_{2f}^* Z_{kf}\end{aligned} \tag{10}$$

where:

Π_f^* = normalized restricted profit function,

p_{if}^* = normalized output prices,

Z_{nf} = quasi-fixed inputs (land, labour, capital, and energy).

Note that capital in the profit function excludes energy capital, but includes buildings, machinery and other equipment. The a's, β's and γ's are parameters to be estimated. Symmetry is maintained by $\beta_{kh} = \beta_{hk}$. The normalized supply equations for vegetables and ornamentals are obtained using Hotelling's lemma.

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$$X^*_{1f} = a_{11}p^*_{1f} + a_{12}p^*_{2f} + \sum_{n=1}^{4} \gamma_{1k}Z_{kf} \tag{11}$$

$$X^*_{2f} = a_{12}p^*_{1f} + a_{22}p^*_{2f} + \sum_{n=1}^{4} \gamma_{2k}Z_{kf}, \tag{12}$$

For every firm *f* the demand equation for the numéraire takes the form:

$$\begin{aligned} X_{mat} &= \Pi^*_f - pq \\ &= \sum_{k=1}^{4} \beta_k Z_{kf} + \frac{1}{2}\sum_{k=1}^{4}\sum_{h=1}^{4} \beta_{kh} Z_{kf}\,\beta_k Z_{hf} \\ &- \frac{1}{2}(a_{11}p^*_{1f}p^*_{1f} + a_{22}p^*_{2f}p^*_{2f}) - a_{12}p^*_{1f}p^*_{2f} \end{aligned} \tag{13}$$

The derivative of the profit function with respect to the quantity of energy input is given by:

$$\frac{d\Pi^*_f}{dE} = \beta_E + \sum_{h=1}^{4} \beta_{Eh} Z_{hf} + \gamma_{1E}p^*_{1f} + \gamma_{2E}p^*_{2f} \tag{14}$$

The value function of the dynamic cost-minimization model is specified as:

$$\begin{aligned} &J(w_1, w_2, rc, E, K, t) = \\ &g_0 + [g_1\, g_2\, g_3\, g_4\, g_5\, g_6] \begin{pmatrix} w_1 \\ w_2 \\ rc \\ E \\ K \\ t \end{pmatrix} + \tfrac{1}{2}(w_1 w_2 rc) \begin{bmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{13} & g_{32} & g_{33} \end{bmatrix} \begin{pmatrix} w_1 \\ w_2 \\ rc \end{pmatrix} + \\ &+ \tfrac{1}{2}(EKt) \begin{bmatrix} Q_{11} & Q_{12} & Q_{13} \\ Q_{21} & Q_{22} & Q_{23} \\ Q_{13} & Q_{32} & Q_{33} \end{bmatrix} \begin{pmatrix} E \\ K \\ t \end{pmatrix} + (w_1 w_2 rc) \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{13} & R^{-1}_{32} & R_{33} \end{bmatrix} \begin{pmatrix} E \\ K \\ t \end{pmatrix} \end{aligned} \tag{15}$$

w_i = normalized energy input prices.

Symmetry is maintained by requiring $g_{12} = g_{21}, g_{13} = g_{31}, g_{23} = g_{32}, Q_{12} = Q_{21}, Q_{13} = Q_{31}$ and $Q_{23} = Q_{32}$. In our framework, it is assumed that the investment demand equation is different for firms where investment is negative, zero or positive. Following

Oude Lansink and Stefanou (1997), the optimal investment regime is given by:

$$\dot{K}^{+} = \gamma^{+} X + u, \tag{16}$$

$$\dot{K} = \begin{cases} \dot{K} = K^{-}, & I < 0 \\ \dot{K} = -\delta K^{-}, & I = 0 \\ \dot{K} = K^{+}, & I > 0 \end{cases},$$

where $X = (w_1, w_2, rc, E, K, t)$. Because investment is a censored variable, an ordinary regression analysis could cause selection bias. We account, therefore, for this selection bias by applying Heckman's procedure via an ordered probit model. The independent variable is investment which is ranked as zero (negative and zero investment) or as one (positive investments) (Oude Lansink and Stefanou, 1997). The estimated parameters of the probit model are used to calculate the inverse Mills ratio (), which is then included as an additional explanatory variable in the investment demand equation:

$$\dot{K}^{+} = \gamma^{+} X + \sigma imr + \varepsilon. \tag{17}$$

Using equations (6) and (17) the demand equation for investment can be expressed as:

$$\dot{K} = (iU - R_{32})K + iR_{32}(g_3 + g_{13}w_1 + g_{23}w_2 + g_{33}rc + R_{31}E + R_{33}t) - R_{32}R_{33} + \sigma imr, \tag{18}$$

where U represents an identity matrix of same dimension as R_{32} (rank one in our case). This equation is a multivariate accelerator model with an adjustment matrix $\dot{K} = (iU - R_{32})(K - \dot{K}^{*})$ where K^{*} is the steady-state stock of energy capital and $(iU - R_{32})$ represents the adjustment rate. The steady-state stock of energy capital is:

$$K^{*} = iNR_{32}(g_3 + g_{13}w_1 + g_{23}w_2 + g_{33}rc + R_{31}E + R_{33}t) - N^2 R_{33} \tag{19}$$

where $N = -(i - R_{32})^{-1}$. The conditional demands for the other netputs and the conditional demand for the numéraire variable input are:

$$X_1^{*} = i(g_1 + g_{11}w_1 + g_{12}w_2 + g_{13}rc + R_{11}E) + R_{12}(iK - K^{*}) + R_{13}(it - 1) + D_1 dummy, \tag{20}$$

$$X_2^{*} = i(g_2 + g_{12}w_1 + g_{22}w_2 + g_{23}rc + R_{21}E) + R_{22}(iK - K^{*}) + R_{23}(it - 1) + D_2 dummy, \tag{21}$$

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$$X_n = i\left(g_4 E + E Q_{11} E - \frac{1}{2}(w_1 g_{11} w_1 + w_2 g_{22} w_2 + rc g_{33} rc) - w_1 g_{12} w_2 \right.$$
$$\left. - w_1 g_{13} rc - w_2 g_{23} rc \right) + g_5(iK - K^*) + Q_{12} E(iK - K^*)$$
$$+ Q_{22} K\left(\frac{1}{2} iK - K^*\right) + g_6(it - 1) + Q_{13} E(it - 1)$$
$$+ Q_{23}(itK - K - t - tK^*) + Q_{33} t\left(\frac{1}{2} it - 1\right). \tag{22}$$

The dummies in equations (20) and (21) are related to firms which produce electricity. Because firms need mainly gas as an input to produce electricity, the dummy is also included in the gas demand function. We have included this dummy variable to distinguish greenhouse firms by their different production technologies. These firms have moved toward new production systems, such as the CHPs, that might be expected to embody different technological characteristics in terms of output and input mix.

To derive the short-term marginal costs of energy (8), we use the estimated parameters from the dynamic framework:

$$C_{E(t)} = i(a_4 + Q_{11}E + Q_{12}K + Q_{13}t ++ R_{11}w_1 + R_{12}w_2 + R_{13}rc) - \dot{K}Q_{12} - Q_{13} \tag{23}$$

To get the optimal energy quantity used as an input (9), equations (13) and (23) are combined. In the long term, energy capital and energy quantity fully adjust to their long-term equilibrium levels. Thus, in the long-term the steady-state stock of capital could adjust towards optimal levels of quantity of capital and energy. The steady-state stock of capital (18) is a function of the optimal quantity of energy used, whereas the optimal energy quantity used is a function of the steady-state stock of capital:

$$K^* = f(w_1, w_2, t, E^*) \tag{24}$$

$$E^* = h(p_{1f}, p_{2f}, w_1, w_2, rc, Z, t, K^*, \dot{K}) \tag{25}$$

By solving the system, we can derive the steady-state stock of capital where energy quantity needed and investment demand also adjust to their optimal levels or vice versa[1].

1 The two simultaneous differential equations cannot easily be solved analytically; however, an approximation to the solution is taken to solve the problem. In our case, investment demand in the long-term ($\dot{K}^*$) is approximated by $\frac{dK^*}{dt}$.

$$K^{*} = f\left(w_1, w_2, t, h(p_{1f}, p_{2f}, w_1, w_2, rc, Z, t)\right), \tag{24a}$$

$$E^{*} = h\left(p_{1f}, p_{2f}, w_1, w_2, rc, Z, t, f(w_1, w_2, t)\right). \tag{25a}$$

The dynamic behaviour of energy demand is summarized in short- and long-term elasticities. Short-term price elasticities of the dynamic cost function are obtained by keeping the quantity of energy capital and energy output constant. Long-term elasticities reflect the responses of various quantities to price changes when energy capital and energy quantity have fully adjusted to their long-term equilibrium levels. The short- and long-term responses of an energy netput, X_n, to a change in price, w_n, are defined as:

$$\varepsilon_{Xw}^{SR} = \frac{dX_n^{*}}{dw_m}\frac{w_m}{X_n^{*}}. \tag{26}$$

$$\varepsilon_{Xw}^{LR} = \varepsilon_{Xw}^{SR} + \varepsilon_{XK^{*}}\varepsilon_{K^{*}w} + \varepsilon_{XE^{*}}\varepsilon_{E^{*}w} \rightarrow \left[\frac{dX_n^{*}}{dw_m} + \frac{dX_n^{*}}{dK^{*}}\frac{dK^{*}}{dw_m} + \frac{dX_n^{*}}{dE^{*}}\frac{dE^{*}}{dw_m}\right]\frac{w_m}{X_n^{*}}. \tag{27}$$

5.3 Data and Estimation

Data from greenhouse firms over the period 2001-2008 were provided by the Agricultural Economic Research Institute (LEI). Firms in the dataset are representative of the Dutch greenhouse sector. This data set contains information on all revenues, expenses and variables on the balance sheets.

The output supply and input demand equations derived from the restricted profit function include four quasi-fixed inputs. These inputs are land (ha), capital quantity (include buildings, machinery, installations and equipment), total energy, and family and hired labour (hours). A time-trend variable is added to capture technological process. Quality-corrected total labour hours are calculated by dividing total labour costs by the wage rate per hour. The quantities of output, materials and energy are measured in constant Euros. A price index for vegetables and energy are used for our output vegetables (sum of different vegetables, such as tomatoes and cucumbers) and total energy output respectively, and Törnqvist price indexes were constructed for the aggregation of ornamentals (consisting of pot plants and cut flowers) and materials (aggregation of seeds, fertilizer, plant protection). Prices of output are not known at the time decisions are made on the use of variables inputs. Using expected output prices is, therefore, preferred rather than actual output prices. Expected output prices were determined as the first lag of the actual prices. The profit function is normalized using the price of materials.

For the dynamic netput demand functions, we have 4 netputs (electricity, gas, an aggregated group of 'other energy', and price of capital), one output (energy quantity) and one quasi-fixed input. The quasi-fixed input is energy capital quantity (includes machinery, installations and equipment). Time is included as a variable to capture autonomous technical progress. Implicit quantities of the energy inputs are computed as the ratio of costs to the corresponding price index. A Törnqvist price index was constructed for the aggregate quantity of 'other energy' (consisting of heat, and 'other fuels'). Expected prices of energy inputs are used in the estimation, by using the first lag of the actual prices. The price of capital is composed of interest costs and depreciation costs. The interest costs are constant among firms but differ over time, while the depreciation rate is constant over time but differs among firms. Prices of gas and electricity are normalized using the price index of the aggregated group 'other energy' to ensure that the value function is linearly homogeneous in prices. Summary statistics of the variables are presented in Table 5.1. The negative value for the input electricity in Table 5.1 is caused by the fact the Dutch greenhouse firms are, on average, net electricity producers. The net electricity quantity as a netput is composed by the electricity quantity bought and used as an input minus the electricity quantity supplied which is sold to the national grid and is therefore (on average) negative.

The inverse Mills ratio, to estimate the investment demand function (equation 18), is derived using an ordered probit model. Because our dataset had only 6 observations with negative investment[2], we used the binary probit model. Control variables were normalized energy input prices, quasi-fixed input energy capital and time.

The price indexes of the profit function and the dynamic cost function vary over years, but not over firms, implying that quality differences and differences in the composition of the input between firms are reflected in the implicit quantity. Moreover, it is assumed that individual firms have access to the same production technology, but that firm-specific factors put constraints on the feasible points of the set of production options. This assumption can be incorporated by a fixed-effects transformation. By including fixed effects, time-invariant quality differences in inputs between firms are controlled. Consistent estimation requires a transformation to eliminate individual effects. A within transformation removes the individual effects by taking deviations from individual means. Another option is to do a first difference transformation (Thijssen, 1996) to eliminate the individual effect. The profit function incorporates fixed-effects by taking first-differences. The transformation in first-differences of the time-trend variable, however, results

2 Our panel data set includes 54.54% observations with a positive investment, 44.79% of observations with no (zero) investment and 0.67% observations with a negative investment.

Table 5.1 Summary Statistics of Key Variables, 2001-2008

Variable		N	Mean	Standard deviation
Static Profit function				
Vegetables output	(€*1000)	144	1496.74	861.63
Ornamentals output (aggregated)	(€*1000)	158	1412.36	978.19
Capital	(€*1000)	302	1787.09	1038.25
Energy quantity	(€*1000)	302	199.21	152.77
Materials quantity	(€*1000)	302	433.59	421.39
Labour	(hrs*1000)	302	5.91	2.35
Land	Ha	302	3.11	1.87
Normalized vegetables price	Index	302	0.968	0.108
Normalized ornamentals price	Index	302	1.037	0.027
Dynamic cost function				
Electricity quantity producers	(€*1000)	95	-163.98	299.00
Electricity quantity users	(€*1000)	207	35.85	51.94
Gas quantity	(€*1000)	302	211.06	181.02
‘Other energy’ quantity	(€*1000)	302	15.16	44.75
Energy capital	(€*1000)	302	1003.91	893.21
Normalized electricity price	Index	302	1.238	0.028
Normalized gas price	Index	302	1.322	0.106
Rental rate of capital	(%)	302	11.07	2.71
Electricity quantity input	(€*1000)	302	46.19	60.72
Electricity quantity sold	(€*1000)	302	73.20	191.03

into a constant and is therefore excluded in the estimation of the profit function. The time variable plays a bigger role in the estimation of investment and energy netput demand and we prefer to keep time in our equations. The energy input demand functions and the investment demand function are, therefore, transformed by taking deviations from the group means instead of first-differencing.

The sample used firms for which at least two years of observations were available. The final panel data set used for estimation includes 302 observations on 97 firms.

5.5 Results

The parameter estimates of the system of equations are not presented, but can be obtained from the authors upon request. Thirty one out fifty seven parameters are insignificant at the 5 percent level (54.4%). The implication of the parameter estimates for input demands can be summarized by calculating the price elasticities (Table 5.2). The elasticities were calculated at the sample mean of the data. For the dynamic function, the own-price elasticity of electricity is divided into two parts: an own-price elasticity with respect to firms which only use electricity as an input and an own-price elasticity with respect to firms which use electricity as an input as well as an output. All own-price elasticities have the expected sign (positive for output supply and negative for input demand). Firms that use electricity as a netput, have a positive own-price elasticity. This results from the fact that it is more profitable for Dutch greenhouse firms to increase their electricity production, if the price of electricity increases. In the short-term, gas and the input electricity as well as gas and the aggregated group 'other energy' are substitutes. The aggregated group other energy consists of heat and other fuels. Many horticulture firms already switched to using more natural gas as a substitute for other fuels, such as coal because natural gas is the cleanest among the fossil fuels. The inputs electricity and the aggregated group 'other energy' are complements. In addition, gas and electricity as a netput are complements, and, although the elasticity is not significant, this makes sense, as a rise in the price of gas makes electricity as a netput less attractive for horticulture firms.

Besides the short term elasticities, we also derived the long term elasticities (eq. 28). In the long term, the magnitudes of the own-price elasticities increase in absolute terms compared to the short term for all energy netputs. Thus, if the absolute value of the own-price elasticity increases, the quantity changes more in the long term compared to the short term. The own-price elasticities have the expected signs, except for the aggregated group of other energy, where in the long term the quantity increases if its price increases. However, the quantity of other energy use is small in most greenhouses. The magnitudes of the own-price elasticities for electricity imply large responses of electricity quantity, both as an input and as a netput. The input gas is a long-term substitute for the netput electricity and a long-term complement for the inputs electricity and the aggregate group other energy. Typically, Dutch greenhouses are heated by a central heating boiler using natural gas, meaning that producers need gas to use their heat (aggregated group other energy). It becomes more profitable for Dutch horticulture firms to produce electricity and become net local electricity producers instead of producing vegetables or ornamentals if the electricity price increases. While gas is used as an input for electricity production, the quantity of gas decreases if the electricity price increases. This substitution effect suggests that the demand for gas for physical output production is more dominant than the demand for gas for producing electricity. By producing less physical output, the demand of gas decreases as well.

If the price of capital increases, firms use more electricity as an input and produce less electricity in the long term compared to the short term. Moreover, firms decrease their optimal stock of capital if the price of capital increases.

Table 5.3 shows the price elasticities with respect to the quasi-fixed inputs. The relation between vegetables output supply and the quasi-fixed inputs land and energy is, as expected, positive. However, for the quasi-fixed inputs labour and capital the effect on output is negative. For ornamentals the relation to the quasi-fixed factors is positive for all inputs, except for capital (not significant at 10%). Both elasticities between vegetable and ornamental output supply and capital are not significant at 10% level. The ornamentals subsector in Dutch horticulture uses more fixed labour than the vegetable sector. The latter needs more temporary workers during summer time. In addition, the vegetable sector makes (already) more use of machinery/industrial equipment. This may explain the negative sign for labour. Energy and materials are substitutes, whereas capital and materials are complements. Horticulture producers need capital to increase their quantity of materials.

If we focus on the energy elasticities, we see that electricity use, gas and the aggregated group 'other energy' increase if the quantity of total energy (E) increases. On the other hand, the quantity of electricity as a netput (negative net input) decreases. This means that less electricity will be produced (and sold to the grid) if the total quantity of energy increases. If the quantity of energy capital increases, a representative greenhouse firm will use more gas and produce more electricity as a netput. The latter results are consistent with the fact that Dutch greenhouse firms invested heavily in CHP installations in our period of consideration (2001-2008) rather than technologies that only have an energy saving effect, such as heat buffers.

The adjustment rate of capital is 32.33 percent, implying that the capital stock adjusted approximately 32 percent per year to the long-term equilibrium level. Other studies in agriculture show rates between 12 percent and 55 percent. We expected to find a high energy capital adjustment rate in Dutch greenhouse horticulture, because the investment rate in general and the innovation and diffusion pace in energy technologies in particular are high in Dutch greenhouse horticulture.

Additionally, the elasticities with respect to optimal quantity of energy are derived. In the short-term, energy is given as fixed whereas in the long-term the

Table 5.2 Price Elasticities in the short and long term

	Price vegetables	Price ornamentals	Price materials	Price electricity	Price gas	Price other energy	Price capital
Short-term elasticities							
Q. vegetables	0.174** *(0.059)*	-0.021 *(0.070)*	-0.153** *(0.049)*				
Q. ornamentals	-0.021 *(0.070)*	0.082 *(0.227)*	-0.062 *(0.183)*				
Q. materials	0.513** *(0.163)*	0.209 *(0.619)*	-0.722 *(0.527)*				
Q. electricity[1]				0.505 *(3.02)*	-0.803 *(3.02)*	0.298 *(0.57)*	0.292 (2.04)
Q. electricity[2]				-2.31** *(0.66)*	3.675** *(0.66)*	-1.365 *(2.60)*	-1.337** (0.447)
Q. gas				0.585 *(0.48)*	-0.972* *(0.52)*	0.387** *(0.20)*	0.302* (0.184)
Q. other energy				-0.081 *(5.33)*	1.579 *(18.05)*	-1.497 *(5.48)*	2.457 (6.356)
Optimal Q. energy	1.671** *(0.000)*	2.270** *(0.000)*	-4.077** *(0.000)*	-6.975** *(0.000)*	-2.61** *(0.000)*	9.58** *(0.000)*	0.071** (0.000)
Long-term elasticities							
Q. electricity[1]				6.779** *(1.374)*	1.492 *(3.019)*	-8.270** *(1.530)*	0.223 *(0.455)*
Q. electricity[2]				-31.00** *(6.286)*	-6.82** *(0.663)*	37.89** *(6.970)*	-1.02 *(2.08)*
Q. gas				-1.088* *(0.602)*	-1.56** *(0.521)*	2.655** *(1.046)*	0.308* *(0.183)*
Q. other energy				-4.89 *(5.73)*	-0.204 *(18.05)*	5.093 *(6.43)*	2.524 *(11.47)*
Optimal stock capital				-1.628 *(3.40)*	3.127* *(1.84)*	-1.499 *(4.21)*	-2.185 *(6.24)*
Optimal Q. energy	2.54** (1.13)	3.720** (1.484)	-6.26** (1.56)	-10.720** *(2.529)*	-3.99** *(1.843)*	14.712** *(4.213)*	0.099 *(6.240)*
Adjustment rate (*i*-R_{32})	32.33%						

Note: Estimated standard error between brackets
Note: Asterisk (*) and double asterisk (**) denote significance at 10% and 5% respectively
Note: Superscript (1) and superscript (2) denote firms which use electricity as netput and firms which use electricity as input only, respectively.

output energy quantity and the quasi-fixed input energy capital can adjust to their optimal levels. The elasticities regarding to the optimal quantity of energy are significant both in the short and long term and have the expected sign. This does not hold for the aggregated group of other energy inputs. However, the use of other energy is limited compared to the other two energy inputs. Moreover, in our period of consideration, net energy demand has gone down due to the underlying rise in energy prices as a result of less purchase of electricity and more production (and sales) of electricity.

Table 5.3 Elasticities with respect to quasi-fixed factors in the short and long term

	Land	**Labour**	**Capital**	**Energy capital**	**Energy**	**Time trend**
Short-term elasticities						
Q. of vegetables	0.617**	-0.274**	-0.035		0.029**	
	(0.054)	*(0.080)*	*(0.052)*		*(0.011)*	
Q. of ornamentals	0.133**	0.584**	-0.030		0.041**	
	(0.051)	*(0.075)*	*(0.048)*		*(0.018)*	
Q. of materials	0.782**	0.541**	0.041		-0.452**	
	(0.148)	*(0.228)*	*(0.126)*		*(0.045)*	
Q. of electricity[1]				0.021	-0.892**	0.010
				(0.031)	*(0.429)*	*(0.240)*
Q. of electricity[2]				-0.095**	4.083**	-0.047
				(0.007)	*(0.094)*	*(0.053)*
Q. of gas				0.018**	0.237**	-0.017
				(0.006)	*(0.068)*	*(0.043)*
Q. of other energy				-0.061	0.737**	0.017
				(0.264)	*(0.394)*	*(0.126)*
Optimal Q. of energy	0.123**	0.391**	-0.002**			
	(0.000)	*(0.000)*	*(0.000)*			
Long-term elasticities						
Optimal Q. of energy	0.189	0.599**	-0.003	-	-	-
	(0.148)	*(0.170)*	*(0.133)*			
Adjustment rate (i-R_{32})	32.33%					

Note: Estimated standard error between brackets
Note: Asterisk (*) and double asterisk (**) denote significance at 10% and 5% respectively
Note: Superscript (1) and superscript (2) denote firms which use electricity as netput and firms which use electricity as input only, respectively.

5.6 Simulations and CO_2 emissions implications

The estimated elasticities (Tables 5.2 and 5.3) show the direct quantities response to a change in price and how the optimal quantity of energy changes if the price of an output or input increases by one percent or if the quantity of a quasi-fixed factor changes by one percent. An increase in the gas price could result from a tax on gas. This implies that a tax on gas may have an effect on CO_2 emissions. The CO_2 sector system is implemented in the Dutch greenhouse horticulture sector starting in 2012. We ignore CO_2 emissions due to the production of electricity and the aggregated group other energy, because natural gas is the major emitter of CO_2 emissions and is responsible for approximately 75 percent of the total energy inputs (Table 5.1). Moreover, CO_2 emissions generated from electricity production are counted to the power plants and not to the horticulture producers. Using our estimated parameters and taking into account direct and indirect effects, one can derive short term and long term elasticities with respect to CO_2 emissions (see Appendix 5A).

Table 5.4 shows the effects of a one percent increase in the input and output prices on the quantity of CO_2 emissions. The differences between the short- and long term are small, suggesting that results of energy policies are unlikely to differ in the short- or long term. These changes are small because of the reverse effects in the long-term. In the long-term, the changes in optimal quantity of energy increases in absolute terms compared to the short-term. According to Table 5.4, a 1 percent

Table 5.4 Price Elasticities with respect to CO_2 emissions[1]

	Quantity of CO_2 emissions	
	Short term	*Long term*
Price of vegetables	0.414	0.413
Price of ornamentals	0.492	0.526
Price of materials	-0.906	-0.940
Price of gas	-1.621	-1.603
Price of electricity	-1.153	-1.161
Price of other energy	2.774	2.765
Price of capital	0.347	0.337

[1] A direct price effect and an indirect price effect via the optimal quantity of energy contribute to the elasticities.

ad valorem tax on the price of gas or electricity result in a decrease of CO_2 emissions by 1.6 percent and 1.2 percent, respectively.

5.7 Conclusions

The ensuing discussion about policies aiming at reducing CO_2 emissions by the horticulture sector needs input on the possible effectiveness of proposed policies and their impact on firms' profitability. The Dutch government wants Dutch greenhouse firms to reduce their energy-use and invest in energy technologies and decrease the quantity of CO_2 emissions. A CO_2 sector system in the Dutch greenhouse horticulture sector started from 2012. Producers are encouraged to emit less and reach the goal of reducing their emissions by 20 percent in 2020. This chapter contributes to this discussion about the most efficient strategy to reduce energy use. Additionally, it contributes to the literature by providing a detailed dynamic model of the demand for different energy components that allows for the option of energy production. The modelling approach generates a number of policy insights that are useful for the design of future energy reducing, energy use efficiency improving and CO_2 emission reducing policies.

The results obtained in this chapter suggest a moderate rate of adjustment of energy capital towards its long-term equilibrium for the Dutch greenhouse sector. Furthermore, in the long-term the optimal quantity of energy decreases, suggesting that, in the long-term, greenhouse horticulture firms focus more on electricity production than on their actual output (i.e. greenhouse vegetables and ornamentals). In addition, if firms invest in energy capital, they will use a larger volume of gas, other energy and electricity production, and lower volumes of electricity as an input. These results suggest that incentives to invest, enhance the use of energy technologies by greenhouse firms. However, a drawback is the increase of CO_2 emissions by using more gas for CHPs. The CO_2 elasticities imply that an increase on the gas price (tax) results into a decrease in CO_2 emissions, however do not have more impact in the long term compared to the short term. A small number of elasticities change significantly in magnitude when analysed in the long-term. This implies that results of a policy can be realized in a short time horizon.

A direction for further research is to simulate some ex-ante energy policy scenarios and future CO_2 emissions policies. Future research would also benefit from additional years of data. The demand of CHPs is stagnating or even declining due to decreasing incentives (such as subsidies) provided by the government, decreasing profits of CHPs (overproduction resulted into extremely low electricity prices) and due to low prices of greenhouse products (Energy Matters, 2011).

However, our empirical results provide detailed insight into the structure of greenhouse production, and specifically in the role of energy use in (Dutch) greenhouse sector.

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References

Agbola, F.W. 2005. Optimal intertemporal investment in Australian agriculture: An empirical investigation. *Agricultural Economics Review* 6: 5-15.

Asche, F., Kumbhakar, S. and Tveteras, R. 2008. A dynamic profit function with adjustment costs for outputs. *Empirical Economics* 35: 379-393.

Chambers, R.G. 1988. Applied Production Analysis: A Dual Approach. Cambridge: Cambridge University Press.

Energy Matters. 2011. Ontwikkeling barometer marktpositie glastuinbouw WKK (in Dutch).Energy Matters.

Epstein, L.G. 1981. Duality Theory and Functional Forms for Dynamic Factor Demands. *The Review of Economic Studies* 48: 81-95.

Epstein, L.G. and Denny, M.G.S. 1983. The Multivariate Flexible Accelerator Model: Its Empirical Restrictions and an Application to U.S. Manufacturing. *Econometrica* 51: 647-674.

Fernandez-Cornejo, J., Gempesaw, C.M., Elterich, J.G. and Stefanou, S.E. 1992. Dynamic Measures of Scope and Scale Economies: An Application to German Agriculture. *American Journal of Agricultural Economics* 74: 329-342.

Howard, W.H. and Shumway, C.R. 1988. Dynamic Adjustment in the U.S. Dairy Industry. *American Journal of Agricultural Economics* 70: 837-847.

Ministerie van Landbouw Natuur en Voedselkwaliteit. 2008. Convenant Schone en Zuinige Agrosectoren The Hague.

Oude Lansink, A. 2003. Technical efficiency and CO2 abatement policies in the Dutch glasshouse industry. *Agricultural Economics* 28: 99-108.

Oude Lansink, A. and Stefanou, S.E. 1997. Asymmetric Adjustment of Dynamic Factors at the Firm Level. *American Journal of Agricultural Economics* 79: 1340-1351.

Oude Lansink, A. and Van Der Vlist, A. 2008. Non-Parametric Modelling of CO2 Emission Quota. *Journal of Agricultural Economics* 59: 487-497.

Pietola, K. and Lansink, A.O. 2006. Energy-saving Technology Choices by Dutch Glasshouse Firms. *Journal of Agricultural Economics* 57: 129-144.

Product Board Horticulture. 2012. Glastuinbouw maakt nieuwe afspraak met overheid over lagere CO2-uitstoot. Available at: “http://www.tuinbouw.nl/nieuws/glastuinbouw-maakt-nieuwe-afspraak-met-overheid-over-lagere-co2-uitstoot” (last accessed June 20th 2012.

Serra, T., Stefanou, S. and Oude Lansink, A. 2010. A dynamic dual model under state-contingent production uncertainty. *European Review of Agricultural Economics* 37: 293-312.

Stefanou, S.E. 1989. Returns to Scale in the Long Run: The Dynamic Theory of Cost. *Southern Economic Journal* 55: 570-579.

Stefanou, S.E., Fernadez-Cornejo, J., Gempesaw, C.M. and Elterich, J.G. 1992. Dynamic structure of production under a quota: The case of milk production in the Federal Republic of Germany. *European Review of Agricultural Economics* 19: 283-299.

Syed, A. 2011. Energy use reduction and input productivity growth in Australian industries. Paper presented at: 55th Conference Australian Agricultural and Resource Economics Society (AARES), Melbourne, Victoria, Australia, February 8-11, 2011.

Thijssen, G. 1996. Farmers’ investment behavior: An empirical assessment of two specifications of expectations. *American Journal of Agricultural Economics* 78: 166-174.

Vasavada, U. and Ball, V.E. 1988. A dynamic adjustment model for U.S. agriculture: 1948-79. *Agricultural Economics* 2: 123-137.

Vasavada, U. and Chambers, R.G. 1986. Investment in U.S. Agriculture. *American Journal of Agricultural Economics* 68: 950-960.

Weersink, A. 1990. Nonrobustness Of Dynamic Dual Models Of The Northeastern And U.S. Dairy Industries. *Northeastern Journal of Agricultural and Resource Economics* 19: 12-16.

Appendix 5A

Elasticities for CO_2

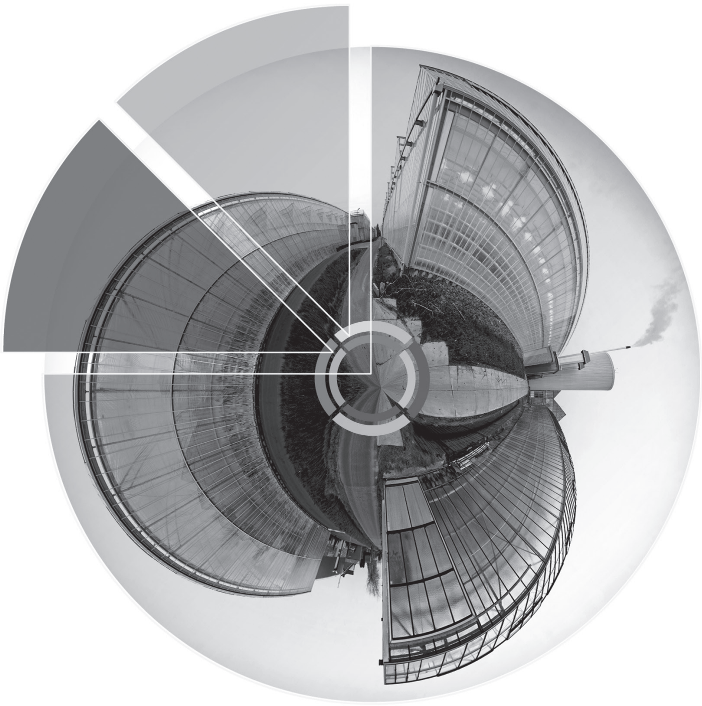
Using both the direct and the indirect effects, one can derive the responses of CO_2 emissions quantity to a change in an energy input price. In the short-term, the CO_2 emission elasticities show the effect of a price change before adjustments in energy capital or energy quantity have taken place. The short term CO_2 emission elasticity is:

$$\varepsilon_{E^* gas}^{SR} = \left[\frac{dGas}{dw_m} + \frac{dGas}{dE^{*SR}} \frac{dE^{*SR}}{dw_m} \right] \frac{w_m}{Gas}.$$

The first term between the brackets corresponds to the direct effect to a change in price , and indicates the response of the quantity of gas to the change in price. The second term between the brackets is the indirect effect that corresponds to the response of gas quantity to a change in the price when the quasi-fixed input energy quantity is optimal in the short term.

In the long term, energy output and the quasi-fixed input energy capital could adjust to their optimal levels. Now the responses of the specific quantity to a gas price change when energy capital and the output energy quantity fully have adjusted to their long-term equilibrium level, are taken into account. In the long term, the responses of gas quantity to a change in optimal energy quantity or optimal energy capital are derived from equations (25a) and (26a). The long term CO_2 emission elasticity is expressed as:

$$\varepsilon_{E^* gas}^{LR} = \left[\frac{dGas}{dw_m} + \frac{dGas}{dE^{*LR}} \frac{dE^{*LR}}{dw_m} + \frac{dGas}{dK^*} \frac{dK^*}{dw_m} \right] \frac{w_m}{Gas}.$$



6

General discussion

6.1 Introduction

The Dutch greenhouse sector has to cope with current socio-economic market changes in order to maintain its strong position in international markets. The following market environment changes were addressed in this thesis: 1) the increasing probability of health scares and border closures due to higher frequency of food safety hazards or reforms in trade regulations; 2) the increasing market power of retailers relative to upstream and downstream stages in the chain; and 3) the pressure for reduction of energy use and CO_2 emissions in greenhouse horticulture production.

The objective of this thesis was to analyse the effects of these changes in the market environment on supply, demand and prices in the Dutch greenhouse vegetable supply chain. As described in Chapter 1, the overall objective was split into four sub-objectives. First, partial equilibrium (PE) models which coped with the changes in agricultural and horticultural product markets, i.e. trade regulations, increasing market concentration, and upcoming environmental regulations and covenants, were reviewed. The review identified desirable technical specifications for future PE models (Chapter 2). Second, a PE model is developed to estimate the impacts of a reduction in domestic consumption due to health scare and a border closure in the export market of Dutch fresh tomatoes. The model quantified the short-term impacts on supply, demand, prices and welfare of the different stages in the chain in an imperfect competitive setting (Chapter 3). In the subsequent chapter the vertical transmission of prices in horticulture supply chains was explored and inferred whether prices adjust asymmetrically. Finally, this thesis analysed Dutch horticultural producers' behaviour and decision-making regarding energy use and investments in energy-related technology (Chapter 5).

This final chapter provides a reflection on the data and methods used in this research (6.3), and it synthesises the results of the different chapters (6.2). Implications for researchers and policy-makers are also discussed. The chapter ends with a summary of the main conclusions of this thesis.

6.2 Synthesis

In this section, we will first discuss the relations between the results and the models of the different chapters. First, the results of the different chapters are linked to changes in the market of Dutch greenhouse products. Next, we will reflect on the connections between the applied models.

6.2.1 Synthesis of Results

The consequences of the aforementioned market environment changes are incorporated in the models developed in Chapters 3-5. Table 6.1 summarizes these consequences on supply, demand and prices for each stage in the chain, including international trade flows.

Both Chapters 3 and 4 focused on market power exerted by retailers or wholesalers. Short-term market power often results in reducing the volume of purchases relative to the competitive level. In the case of buyer power, prices sink below the competitive level. Exerting buyer power can result into insecurity of supply and demand (Sexton, 2013) which is not in the long term interest of wholesalers or retailers. The results of Chapter 3 showed that Dutch retailers faced a very elastic supply elasticity. Hence, oligopsony power between retailers and wholesalers did not significantly affect wholesaler's prices or welfare. The effect of retail oligopsony power was very small and only noticeable in the prices to the consumers (see Table 6.1). Further, the results of Chapter 4 suggested the existence of wholesale oligopoly power in the onion chain. Shocks in onion wholesale prices affect consumers' welfare: retail prices increase permanently. Although Chapter 4 did not find any evidence of retail oligopoly power in the Dutch greenhouse vegetable chain, Chapter 3 showed the possible effects of retail oligopoly power assuming retail market power. Modest levels of retail oligopoly power did negatively affect the welfare of consumers.

Besides market power impacts, the effects of a reduction in domestic and export consumption resulting from a health scare, and a subsequent border closure in the export market of Dutch fresh tomatoes were considered. Both hazards led to a shift in consumer demand and as a consequence, all the prices throughout the chain decreased (Table 6.1). The model assumed that Dutch producer's supply could not change in the short term and therefore, the model assumed that it was fixed. This assumption can be justified by the results of Chapter 5. In this chapter, the short- and long term supply elasticities were estimated. The short-term output price elasticity of vegetables is small (0.17). This indicates that when using annual data, in the short term the quantity is inelastic to price changes. A border closure affected the sector only in one season (less than one year), which implies that the elasticity has to be even smaller. Dutch greenhouse producers collected most of the welfare losses within the chain. A border closure had negative effects on Dutch producers while retailers and consumers benefitted from it (Chapter 3). Overall, Dutch producer prices responded negatively to a shock in the export price (Chapter 4).

The changes in the output prices of producers can indirectly be linked to their energy use and the associated capital investments. The supply elasticities found in Chapter 5 showed the effect of a 1 percent increase of producer prices on producer supply and the subsequent quantity of consumed energy. If the price of vegetables decreases, the quantity of energy used will decrease as well. Subsequently, the results pointed out that, if the total quantity of used (or demanded) energy decreases, more electricity will be produced (and sold to the grid). Dutch producers are less vulnerable to a border closure (Chapter 3) or a shock in downstream prices (Chapter 4) if they are able to diversify their output and sell, for example, electricity to the national grid.

Table 6.1 Overview of expected consequences of changes in the market environment on supply, demand and prices in the Dutch horticulture chain.

		Quantity Supplied			Quantity Demanded		Prices				
	Chapter	**P**[1]	**W**	**I**	**R**	**E**	**P**	**W**	**R**	**E**	**I**
3	Trade Regulations[2]	n.a[3,4]	+	-	+	-	-	-	-	-	-
3	Health Scare	n.a	-	-	-	+	-	-	-	-	-
3	Retail Oligopoly	n.a	0	0	-	0	0	0	+	0	0
3	Retail Oligopsony	n.a	0	0	-	0	0	0	+	0	0
4	Retail Oligopoly						0	0	0	0	0
4	Wholesale Oligopoly						+	+	+	+	+
5	Reduction CO_2 emissions[2]	-									

[1] P=producer stage; W=wholesale stage; R=retail stage; E=international export flows; I=international Import flows.
[2] Trade regulations refer here to a border closure by an important export country; Reduction of CO_2 emissions refers to a short-term change.
[3] n.a. = not applicable; 0= effects are negligible or less than 1% in absolute terms; += positive effect; - = negative effect;
[4] Producer supply is modeled as fixed in Chapter 3 and, therefore, does not give any change in supply.

6.2.2 Synthesis of applied models

The review conducted in Chapter 2 of this thesis concluded that most existing horticulture PE models only deal with trade regulations, such as tariff reductions and import quotas. Horticulture PE models dealing with environmental regulations and covenants (e.g. European Union (EU) climate policy or EU CO_2 trading system), or market power were not very common. According to our review of Chapter 2, an improved model of the impact of the aforementioned market environment changes would be a multi-product, multi-stage, multi-country PE model that considers products as imperfect substitutes and uses econometrically estimated parameters and trade flows. The improved model also has to account for dynamics and seasonality of supply and demand. Table 2.4 in Chapter 2 provided an overview of the current stage and desirable future specifications of greenhouse PE models. Although those specifications hold for PE models, Table 6.2 shows which specifications were incorporated in the models of Chapters 3-5 of this thesis. In Chapter 3, a greenhouse horticulture PE model is developed which coped with trade regulations and market power. With the exception of dynamics and the heterogeneity of products (imperfect substitutes), the model in Chapter 3 addressed all specifications identified in Table 6.2. Chapter 2 also mentions that comparative static approaches are more appropriate when analysing the effects of market power (Réquillart et al., 2008). Product heterogeneity may influence the retailers' or wholesalers' decision regarding different prices and retail margins. Since specific data for every stage in the chain were lacking, this was not feasible. Chapter 2 also noted that it is essential to account for asymmetric price adjustments when modelling imperfections in an agro-food supply chain. Chapter 4 did account for asymmetric price transmission along fresh vegetable supply chains, including international trade flows and market power exerted by the wholesale and retail stages.

As Table 6.2 shows, all desirable future specifications of greenhouse horticulture models are incorporated in at least one of the models used in this thesis. Of all specifications, dynamics and imperfect substitution received the least attention. Chapters 4 and 5 incorporated dynamics in the model. However, Chapter 4 accounted for dynamics only in the empirical model. Chapter 5 took into account dynamics and the possibility of using specialized energy-related equipment. By doing so, this model was able to determine the optimal quantities of energy use and energy-related capital. Products viewed as imperfect substitutes were only incorporated in Chapter 5 (Table 6.2). This chapter accounted for the option to producers to produce electricity in addition to producing vegetables or ornamentals.

6.3 Methodological Design

The models used in this thesis involve a number of assumptions which may have influenced the results. First, this research is restricted to the greenhouse horticulture chain. As a result, the partial equilibrium model developed in Chapter 3

Table 6.2 Specifications incorporated in the models developed in this thesis.

	Chapter		
Specifications	**3**	**4**	**5**
Multi product	apl[1]	x	x
Imperfect substitutes	-	-	x[4]
Dynamics	-	+/-[2]	x
Bilateral trade flows	x[3]	x[3]	-
Econometric estimation	x	x	x
Multi country	x	x[5]	-
More levels of the chain	x	x	-

[1] apl = applicable, if data are adapted to the particular product; x = present or used; - = missing or not used.
[2] +/- = the model accounted for dynamics in the empirical model, however, the theoretical model is based upon a comparative static approach.
[3] Trade flows are incorporated, but not modelled using the Armington assumption.
[4] The supply and demand of energy is treated as an imperfect substitute.
[5] Import and export prices are incorporated in Chapter 4.

only considered price changes in the Dutch greenhouse vegetable market and did not include effects on other sectors of the economy. This limitation in scope is often considered as a disadvantage of PE models. For example, a border closure may also affect the transportation sector. However, the effects would probably be rather small because the transportation sector does not depend only on the greenhouse vegetable industry or, more specifically, the greenhouse tomato sector.

Second, this thesis employs the conjectural variation approach as a theoretical basis to examine the consequences of market power (Chapters 3-4). Generally, two main frameworks are used to examine market power in a food supply chain: the Structural-Conduct-Performance (SCP) and the New Empirical Industrial Organization (NEIO) frameworks. The SCP approach examines market structures and investigates whether high levels of market concentration result in collusive behaviour (Bain, 1951). The most frequently applied measures of concentration are the concentration ratio (CR) and Herfindahl-Hirschman Index (HHI). Concentration ratios capture structural features of a market and these models link competition to concentration (Bikker and Haaf, 2002). The main limitation of the SCP framework is that a measure of concentration does not enable one to draw conclusions about the competitive performance in a particular market. Even in a highly concentrated market, competitive behaviour is still possible. Several studies, such as Schroeter and Azzam (1991), measured market power in food supply chains and found a declining trend in market power while market concentration increases. On the other hand, the NEIO framework makes market structures endogenous and measures the competitive conduct behaviour of firms (Iwata, 1974; Bresnahan, 1982; Lau, 1982). These models do not use explicit information about the structure of the market (concentration) (Myers *et al.*, 2010). Limitations of the NEIO approach are the difficulty with understanding and interpreting the behavioural market power parameter and the underlying assumption of constant returns to scale, because increasing returns to scale may explain increasing concentration (Gardner, 1975; Goodwin, 1994). However, Heien (1980) argues that the assumption of a fixed proportion technology is realistic at the retail stage, because the product is not further processed. In this thesis, the latter argument also holds throughout all stages of the chain. Fresh greenhouse horticulture products are not processed (besides possible packaging).

Two empirical approaches have been used to estimate the impact of market power. The first is the structural approach, based on market equilibrium models (supply and demand) and is used in Chapter 3. Structural approaches are based on micro-economic theory, but are often difficult to operationalize due to lack of data. The second is the non-structural approach, which is based on time-series estimation and is used in Chapter 4. The non-structural approach involves time-series modelling and is easier to implement, but lacks a microeconomic foundation. Consequently, both approaches have their advantages and disadvantages and, Digal and Ahmadi–Esfahani (2002) suggest to use a combination of these methods. The non-structural approach used in Chapter 4, has been preceded by a theoretical NEIO model as basis.

In this thesis, it is further assumed that the wholesale stage does not exert market power over producers. The main reason is that Dutch producer associations cooperate closely with wholesalers in greenhouse fruit and vegetables. The collection and sales of fresh produce are integrated activities. Producers and wholesalers act together to serve joint interests. During the last decade, both producer associations and wholesalers became very large and played an important role in determining the selling price to domestic retailers or to international markets.

Lastly, we used several data sets within this research. The sample for estimating producers' behaviour (Chapter 5) consisted of panel data from the Agriculture Economic Research Institute (LEI). The panel structure of this dataset allowed for employing a fixed effects model, which means that the model accounts for unobserved differences among firms. Since the firm-specific effects are taken into consideration by taking first-differences or deviations from the means, these effects can only be calculated ex-post. The interpretation of these firm-specific effects is, therefore, not always clear. By using fixed effects it is not possible to assess the effect of variables that have little within-group variation. Moreover, fixed effects models cannot identify the effect of fixed variables on the quantity of a variable input. Chapter 3 used monthly data at the sector level and Chapter 4 used aggregated weekly firm-level data. The data used in the retail stage represented only large firms and did not cover small vegetable stores. However, 84 percent of the vegetables are sold through the retail channel in the Netherlands (HBD, 2012). For both chapters, we used individual selling prices of large retailers and aggregated these data by multiplying the prices with market shares. Due to lack of data, Chapter 3 did not include the revenues and the quantities of discount chains. The discount chains, however, account for less than 15 percent of the retail fresh vegetable market (NMa, 2009; HBD, 2012). In Chapter 4, we also used observed purchase price data of the large retailers as a proxy for the wholesale price.

Firms have different cost structures which affect, for example, the degree of market power. Therefore, analysis for an individual greenhouse product (such as tomato or red pepper in respectively Chapters 3 and 4) is preferred at a disaggregated level and thus firm-level data. In both Chapters 3 and 4, we used sector-level data, because data availability is often a limiting factor and conjectural variation elasticities are not known at the firm-level.

Nevertheless, the models developed throughout this thesis can be applied to other chains, provided that the data are adapted to that particular chain. The partial equilibrium model in Chapter 3 has been built in a generic way and can be easily extended to investigate various aspects of trade regulations, such as supply or greenhouse-gas quotas, import tariffs, and ex-ante assessments of producer price support (minimum prices) or other supply chain regulations.

6.4 Scientific implications & Suggestions for further research

Past research has often focused on assessing the impacts of policies in agriculture on output markets. However, most of these policy studies focused on markets of bulk commodities, such as grains and cotton. Impacts of policies on markets of greenhouse products are scarce (Rickard and Sumner, 2008). This thesis contributes to the scientific literature by developing and using models specifically for the greenhouse vegetable supply chain.

Dutch greenhouse producers are mostly affected by the current market environment changes. As an example, producers were strongly hit by the EHEC discovery and subsequent border closure (Chapter 3). The crisis led to bankruptcy of many Dutch greenhouse firms which were not able to cope with the subsequent economic losses. Dutch greenhouse producers incurred most of the losses, suggesting that the resilience of the Dutch greenhouse chain is not high. Resilience refers to the ability of firms to react quickly to reduce the probability and the economic consequences of an unpredictable event once it occurs (Carpenter *et al.*, 2001). The developed models in this thesis did not predict whether firms would exit the sector. Further research is needed to assess the resilience of the different stages of the Dutch greenhouse supply chain. The PE model developed in Chapter 3 can be extended to include the producer supply as an endogenous variable and include as well the inputs of the producer stage (i.e. energy, land, capital). Future research should, therefore, consider a border closure's long-term effect by including the producers' production, energy use, and investment choices behaviour. Then, the model can also account for firms which exit the sector.

This thesis considered multiple stages of the chain in Chapters 3 and 4. After all, the current economic and institutional market environment changes in this chain affect not only producers, but affect other stages of the chain as well. The existing literature on market concentration and vertical price transmission in the greenhouse vegetable chain, only took into account a limited number of levels of the chain (Just and Chern, 1980; Melnick and Shalit, 1985; Goetz *et al.*, 2008; Réquillart *et al.*, 2008; Mesa and Gómez, 2011). However, future research can enrich the model by including catering and restaurants as an extra retail outlet.

Because the consolidation process among retailers is still going on in Europe, their concentration ratio keeps increasing. The question whether the agricultural food, or more specifically the greenhouse horticulture, industry is characterized by an imperfectly competitive market setting was a much debated issue in the scientific and policy fields. Chapters 3 and 4 both considered the possible effects of market power on prices in the fresh vegetable chain. As Myers *et al.* (2010) and Meyer and von Cramon-Taubadel (2004) concluded, greater attention should be given to the theoretical foundation of price transmission models throughout the chain. This thesis provided a theoretical underpinning of the relationship between prices, international trade and market structure characteristics in all stages of the chain. Furthermore, this thesis used a unique data set for analysing the price transmission along the chain in Chapter 4. Wholesale prices (purchase prices of the retailers) are often not known and proxies for the prices (i.e. export prices) are used or this stage is ignored. Within Chapter 4, observed prices were used. However, the role of Dutch greenhouse cooperatives and the role of possible vertical contracts can be investigated in further research to analyse the degree of price transmission between Dutch producers and wholesalers.

The ensuing discussion about reducing CO_2 emissions by the greenhouse sector needs input on the effectiveness of proposed policies and their impact on firms' profitability. Simulation models would be a proper instrument to estimate the effectiveness and impact of different policy scenarios that geared to force greenhouse producers changing from fossil to sustainable energy sources. A specific characteristic of the Dutch greenhouse supply chain is that the greenhouse firms are energy-intensive users and, even more, some large firms are also energy suppliers. Chapter 5 zoomed in on this stage and took into account that producers could have two outputs: electricity output and greenhouse horticulture output. Therefore, not only the optimal quantity of energy-related capital has been derived, but also the optimal quantity of energy. However, the research on investment behaviour in energy-related capital was based on data collected over the years 2000-2008. Since then, the market price of electricity decreased and thus the investment behaviour may now be very different. Future research would benefit to expand on periods after 2008 to current years.

6.5 Policy Implications

Energy policies related to adaptation to and mitigation of climate change, are reasons why the modelling of the Dutch greenhouse sector remains important. Since enhancing sustainability and reduction of dependence on fossil energy are key issues for policy-makers, the derived optimal quantities of energy use and energy-related capital generate a number of new policy insights. As mentioned in Chapter 5, the Dutch greenhouse sector has made agreements with the Dutch government whereby targets were set for energy savings and the production of sustainable energy. The two parties agreed to reduce the total CO_2 emissions of greenhouse production in 2020 by 45 percent compared to 1990 levels. According to the results of Chapter 5, incentives to invest in CHPs do not result in a decline in CO_2 emissions, and greenhouse output decreases. In the long term, however, the use of a CHP results in a decrease in the total demanded net energy. Because nowadays the market price of electricity decreased, greenhouse producers sell the produced electricity for a lower price than the price that prevailed at the time the investment in CHP took place (Energy Matters, 2011; Engelenburg, 2012). The demand of CHPs is, therefore, stagnating or even declining (Energy Matters, 2011; Postma, 2012).

The results in Chapter 3 pointed out that all stages in the greenhouse vegetable supply chain are affected by a health scare or border closure caused by phytosanitary problems. A border closure increased the welfare of retailers and consumers, but decreased producers' and total welfare. Moreover, a border closure did not only affect the tomato chain in the Netherlands, but also the prices and quantities in the import and export countries of the Netherlands. Traceability systems may be used to improve the management of information among the stages in a supply chain (Hobbs, 2004). Although these preventive measures can help in mitigating the effect of outbreaks of food safety hazards and subsequently border closures, it is impossible to entirely avoid them.

As far as the policy implications are concerned, the results of this thesis indicate that there is no evidence of negative impact of market power between retailers and wholesalers in the Dutch greenhouse vegetable chain. In 2012, the Netherlands Authority for Consumers and Markets (ACM) fined three red pepper wholesale/producer cooperatives that had formed a price cartel to keep wholesale prices high. Moreover, ACM fined producers of onions who reduced onion supply to increase prices (NOS, 2012; NMa, 2013). Within this thesis, evidence of market power between retailers and wholesalers has not been found in the red pepper industry, but onion wholesalers seemed to exert oligopoly power that lead to permanent price increases. Consumers are also negatively affected by retail oligopoly power. Although our reported results did not find any evidence of retail oligopoly power in the greenhouse vegetable market, regulatory authorities can keep track of the competition exerted by retailers.

6.6 Summary of main conclusions

The major conclusions of this thesis are:

- Existing partial equilibrium models on the horticulture sector focus on trade regulations and often ignore market concentration and environmental concerns (*Chapter 2*).
- The negative impacts on producer prices resulting from a decline in domestic consumer and export demand which occur simultaneously with a border closure, are three times higher than the impacts on retail prices in the high season (*Chapter 3*).
- In the short term, Dutch retailers and consumers gain welfare due to a border closure (*Chapter 3*).
- Retail buyer power does not affect upstream prices, even if a health scare or a border closure by an important vegetable export country for the Netherlands takes place (*Chapter 3*).
- Price shocks along the entire greenhouse red pepper supply chain fade out and prices return to their original equilibria, whereas price shocks at the wholesale level lead to permanent price changes in the onion chain (*Chapter 4*).
- Red pepper producers adjust in the short-term their prices more rapidly upward to retail price increases, and adjust slower to retail price decreases (*Chapter 4*).

- It takes approximately 2 years to bridge half of the gap between actual and optimal levels of energy-related capital in the Dutch greenhouse sector (*Chapter 5*).
- Electricity production is a substitute for vegetable output production on specialised greenhouse vegetable firms (*Chapter 5*).
- Greenhouse vegetable firms which invest in energy-related technologies satisfy the pressure to reduce total net energy, but consume more fossil energy sources *(Chapter 5).*

References

Bain, J.S. 1951. Relation of Profit Rate to Industry Concentration: American Manufacturing, 1936-1940. *The Quarterly Journal of Economics* 65: 293-324.

Bikker, J.A. and Haaf, K. 2002. Competition, concentration and their relationship: An empirical analysis of the banking industry. *Journal of Banking & Finance* 26: 2191-2214.

Bresnahan, T.F. 1982. The Oligopoly solution concept is identified. *Economics Letters* 10: 87-92.

Digal, L.N. and Ahmadi–Esfahani, F.Z. 2002. Market power analysis in the retail food industry: a survey of methods. *Australian Journal of Agricultural and Resource Economics* 46: 559-584.

Energy Matters. 2011. Ontwikkeling barometer marktpositie glastuinbouw WKK (in Dutch).Energy Matters.

Engelenburg, H., 2012. Lichtpuntje voor de glastuinders. Het Financieele Dagblad. 5 December 2012.

Gardner, B.L. 1975. The Farm-Retail Price Spread in a Competitive Food Industry. *American Journal of Agricultural Economics* 57: 399-409.

Goetz, L., von Cramon-Taubadel, S. and Kachel, Y. 2008. Measuring Price Transmission in the International Fresh Fruit and Vegetable Supply Chain: The Case of Israeli Grapefruit Exports to the EU. Discussion Paper 10.08.

Goodwin, B.K. 1994. Oligopsony Power: A Forgotten Dimension of Food Marketing? Discussion. *American Journal of Agricultural Economics* 76: 1163-1165.

HBD. 2012. Bestedingen en marktaandelen. Available at: "http://www.hbd.nl/pages/15/Bestedingen-en-marktaandelen/AGF-groentezaken/Groenten-vers.html?subonderwerp_id=79" (last accessed 19th February 2013).

Heien, D.M. 1980. Markup Pricing in a Dynamic Model of the Food Industry. *American Journal of Agricultural Economics* 62: 10-18.

Hobbs, J.E. 2004. Information asymmetry and the role of traceability systems. *Agribusiness* 20: 397-415.

Iwata, G. 1974. Measurement of Conjectural Variations in Oligopoly. *Econometrica* 42: 947-966.

Just, R.E. and Chern, W.S. 1980. Tomatoes, Technology, and Oligopsony. *The Bell Journal of Economics* 11: 584-602.

Lau, L.J. 1982. On identifying the degree of competitiveness from industry price and output data. *Economics Letters* 10: 93-99.

Melnick, R. and Shalit, H. 1985. Estimating the Market for Tomatoes. *American Journal of Agricultural Economics* 67: 573-582.

Mesa, J.C.P. and Gómez, E.G. 2011. Asymmetric Margins in Prices and Retail Supply Chain Integration: The Spanish Vegetable Case. *Journal of International Food & Agribusiness Marketing* 23: 211-230.

Meyer, J. and von Cramon-Taubadel, S. 2004. Asymmetric Price Transmission: A Survey. *Journal of Agricultural Economics* 55: 581-611.

Myers, R.J., Sexton, R.J. and Tomek, W.G. 2010. A Century of Research on Agricultural Markets. *American Journal of Agricultural Economics* 92: 376-403.

NMa. 2009. Prijsvorming in de agri-food sector.The Hague: Nederlandse Mededingingsautoriteit (NMa).

NMa. 2013. NMa beboet uienhandel. Available at: "http://www.nma.nl/documenten_en_publicaties/archiefpagina_nieuwsberichten/nieuwsberichten/2013/03_13_nma_beboet_uienhandelaren_voor_kartel.aspx" (last accessed 5th March 2013).

NOS. 2012. Kartelboete paprika- en uientelers. Available at: "http://nos.nl/artikel/380362-kartelboete-paprika-en-uientelers.html" (last accessed 15 June 2012).

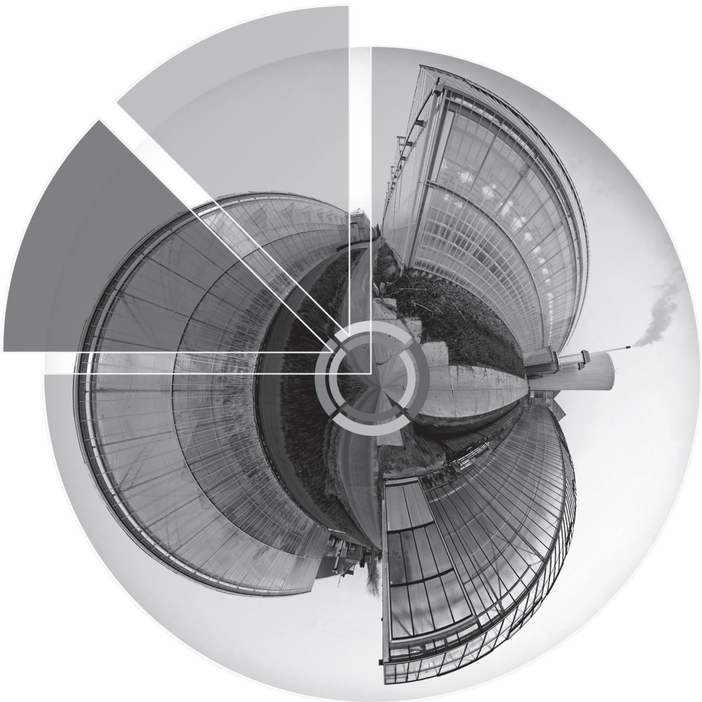
Postma, R., 2012. Toen onze paprika's nog de wereld overvlogen. NRC Handelsblad. 18 December 2.

Réquillart, V., Simioni, M. and Varela Irimia, X. 2008. Imperfect competition in the fresh tomato industry. Paper presented at: EAAE International Congress, Ghent, Belgium, August 26 - 29.

Rickard, B.J. and Sumner, D.A. 2008. Domestic Support and Border Measures for Processed Horticultural Products. *American Journal of Agricultural Economics* 90: 55-68.

Schroeter, J. and Azzam, A. 1991. Marketing Margins, Market Power, and Price Uncertainty. *American Journal of Agricultural Economics* 73: 990-999.

Sexton, R.J. 2013. Market Power, Misconceptions, and Modern Agricultural Markets. *American Journal of Agricultural Economics* 95: 209-219.



Summary

Samenvatting

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Curriculum Vitae

Education Certificate

Summary

The Dutch greenhouse sector has to cope with economic and institutional changes in the supply chain to maintain its strong position in international markets. Examples are the changing energy policies and the on-going consolidation among retail companies. Dutch horticulture producers have to comply with the agreements they made with the Dutch government in which targets for energy saving and production of sustainable energy were set. The greenhouse sector is indeed the most energy-intensive sector in the Dutch agriculture. Because of the intensity of their energy use and to alleviate the burden of these agreements, the government provided subsidies and tax incentives to encourage greenhouse firms to invest in energy-saving equipment and sustainable energy innovations. Obviously, such changes affect the current and future economic and environmental performance of horticulture. Further, it is hypothesized that the consolidation among retailers enables the latter to exercise buying and selling market power at the detriment of consumers and other actors in the supply chain.

Together, these observations resulted in the overall objective of this research, e.g., to analyse the consequences of economic and institutional changes in the Dutch greenhouse horticulture supply chain on supply, demand and prices throughout the chain. The following changes were addressed in this thesis: 1) the increasing probability of food safety hazards, health scares and reforms in trade regulations which may lead to border closures and subsequent drops in demand; 2) the increasing market power of retailers relative to upstream and downstream stages in the chain and 3) the demand for the reduction of energy use and CO_2 emissions in greenhouse horticulture production. Chapter 2 reviewed partial equilibrium models which coped with the changes in markets of agricultural and horticultural outputs. The consequences of these market changes are incorporated in the models developed in Chapters 3-5.

In Chapter 2, desirable technical specifications for future partial equilibrium models were identified. The review found that horticulture partial equilibrium models dealt in detail with changes in trade regulations However, chain concentration and environmental concerns are much less taken into account by the currently available models. According to the same review, an improved model of the impact of the aforementioned market environment changes should be a multi-product, multi-stage, multi-country partial equilibrium model that considers products as imperfect substitutes and that uses econometrically estimated parameters and trade flows. The improved model also has to account for dynamics and seasonality of supply and demand.

In Chapter 3, such an improved partial equilibrium model is developed and used to analyse the short-term impacts of a reduction in domestic and export

consumption due to a health scare and border closure in the export market of Dutch fresh tomatoes. The model quantified the short-term impacts on supply, demand, prices and welfare of the different stages in the chain in an imperfect competitive setting. The model takes into account international trade, market power at the retail level and seasonality effects. With the exception of the dynamics and the heterogeneity of products (imperfect substitutes), the model in Chapter 3 addressed all specifications of the described improved model in Chapter 2. The results implied that a border closure has higher significant impacts on all stages throughout the chain than health scare issues. If consumer and export demand declines simultaneously with the occurrence of a border closure, the impact on producer prices is more than three times the impact on retail prices. On the other hand, Dutch retailers and consumers benefit from a border closure. When competition at the retail level increases, total welfare losses are higher. The net change in domestic total welfare is more negative in the high production season than in the low production season.

In Chapter 4, the vertical transmission of prices in horticulture supply chains was assessed and asymmetric price transmission was tested. The chapter provided a theoretical underpinning of the long-term relationships between prices and international trade by means of vector error correction and vector auto regressive models. Asymmetries in price transmission are examined using the Houck approach as well as the error-correction approach. Observed prices at the producer, wholesale, international trade and retail stages of the red pepper and onion chains were used. The impulse response analyses showed that red pepper prices return to their long-term equilibria relatively quickly, whereas onion prices settled at a new equilibrium after a price shock. Market power in the wholesale sector affected the responses of onion prices but has little or no effect on the responses of red pepper prices. Market power in the retail sector did not affect the onion prices or the red pepper prices. The results suggested asymmetric adjustment in producers-wholesale and international trade–producer relationships in the Dutch onion supply chain. The results also showed that red pepper producers adjust their prices asymmetrically to changes in retail prices.

Chapter 5 zoomed in on the producer stage of the chain by describing horticulture producers' behaviour and decision making regarding their output supply, energy use and investments in energy-related technology. The fact that producers are both energy users and energy suppliers was also taken into account. The behaviour of the firm is modelled using a framework that combines a dynamic cost function and a static profit function. The optimal quantity of energy is derived from the link between these two functions. The model is applied to a panel of Dutch firms specialized in the production of vegetables, pot plants and cut flowers over the period 2001-2008. The results obtained in this chapter suggest a moderate

rate of adjustment in the quantity of energy related capital, i.e. 32 percent, of energy-related capital towards its long-term equilibrium. It takes approximately 2 years to bridge half of the optimal level of energy-related capital, such as equipment to produce electricity. Moreover, in the long term most firms shift from being net electricity users to net electricity producers. For Dutch greenhouse vegetable producers, producing electricity is a substitute to producing vegetables, pot plants and cut flowers. Investing in energy-related capital contributes to reducing net energy use, however, it increases the quantity of CO_2 emissions due to an increase in electricity production.

Chapter 6 provided a reflection on the data and methods used in the research and synthesised the results of the different chapters. All the desirable specifications of greenhouse horticulture models as identified in Chapter 2 were incorporated in at least one of the models used in this thesis. The different models developed in this thesis can be applied to other chains, provided that the data are adapted to that particular chain. As far as the policy implications are concerned, the results of this thesis indicate that there is no evidence of market power between retailers and wholesalers in the Dutch greenhouse vegetable chain. The derived optimal quantities of energy use and energy-related capital generated a number of new policy insights for the field of sustainability enhancement and reduction of CO_2 emissions. Incentives to invest in combined heat and power equipment did not result into a decline in CO_2 emissions, and greenhouse output decreased. Based on the key findings of the thesis, the following major conclusions can be drawn.

- Existing partial equilibrium models on the horticulture sector focus on trade regulations and often ignore market concentration and environmental concerns (*Chapter 2*).
- The negative impacts on producer prices resulting from a decline in domestic consumer and export demand which occur simultaneously with a border closure, are three times higher than the impacts on retail prices in the high season (*Chapter 3*).
- In the short term, Dutch retailers and consumers gain welfare due to a border closure (*Chapter 3*).
- Retail buyer power does not affect upstream prices, even if a health scare or a border closure by an important vegetable export country for the Netherlands takes place (*Chapter 3*).
- Price shocks along the entire greenhouse red pepper supply chain fade out and prices return to their original equilibria, whereas price shocks at the wholesale level lead to permanent price changes in the onion chain (*Chapter 4*).
- Red pepper producers adjust in the short-term their prices more rapidly upward to retail price increases, and adjust slower to retail price decreases (*Chapter 4).*

- It takes approximately 2 years to bridge half of the gap between actual and optimal levels of energy-related capital in the Dutch greenhouse sector (*Chapter 5*).
- Electricity production is a substitute for vegetable output production on specialised greenhouse vegetable firms (*Chapter 5*).
- Greenhouse vegetable firms which invest in energy-related technologies satisfy the pressure to reduce total net energy, but consume more fossil energy sources *(Chapter 5).*

Samenvatting

De bedrijven in de Nederlandse glastuinbouwketen staan bloot aan veranderingen in hun economische en institutionele omgeving. Zij moeten continu inspelen op deze veranderingen om hun sterke internationale positie te kunnen behouden. Voorbeelden van deze veranderingen zijn de wijzigingen in het energiebeleid en een consolidatietrend onder supermarkten. Het vermoeden bestaat dat deze consolidatie kan resulteren in marktdominantie van de supermarkten ten opzichte van hun leveranciers en de consument. Daarnaast zijn Nederlandse glastuinbouwtelers ook gehouden aan afspraken met de Nederlandse overheid op het gebied van energiebesparingen en duurzame energie. De glastuinbouwsector is immers de meest energie-intensieve sector in de Nederlandse landbouw. Om investeringen in energiezuinige technologie te bevorderen, ontvingen de glastuinbouwbedrijven de voorbije jaren subsidies en fiscale voordelen. Uiteraard zijn de vermelde veranderingen van invloed op de huidige en toekomstige economische prestaties van de sector.

De doelstelling van dit onderzoek was daarom om de gevolgen van veranderingen in de marktomgeving op aanbod, vraag en prijzen in de gehele Nederlandse glastuinbouw keten te analyseren. Dit proefschrift behandelt de volgende veranderingen: 1) handelsvoorschriften en crisissen op het gebied van voedselveiligheid die tot sluiting van exportmarkten leiden; 2) de toenemende macht van supermarkten en groothandelaren ten opzichte van hun leveranciers en de consument en 3); de wens om energieverbruik en CO_2-uitstoot in de productie te beperken.

Het proefschrift begint met een overzicht van de literatuur over partiële evenwichtsmodellen die de veranderingen in de markt voor land- en tuinbouwproducten analyseren. De gevolgen van deze veranderingen voor de glastuinbouwsector zijn opgenomen in de hoofdstukken 3-5.

Hoofdstuk 2 identificeert gewenste specificaties voor toekomstige partiële evenwichtsmodellen. In de review concluderen we dat veranderingen in handelsbeleid al op een gedetailleerde wijze voorkomen in de huidige partiële evenwichtsmodellen van de tuinbouw, terwijl veranderingen in ketenconcentratie, marktmacht en milieubeleid in mindere mate voorkomen. Daarnaast geven de conclusies uit Hoofdstuk 2 weer welke specificaties een verbeterd partieel evenwichtsmodel moet bevatten, zodat dit model beter toepasbaar is voor de tuinbouw en tevens veranderingen in de marktomgeving kan analyseren. De gewenste specificaties zijn als volgt: het model kan effecten in meerdere landen en van meerdere producten gelijktijdig berekenen, evenals de mogelijkheid om de effecten in meerdere schakels van de keten te analyseren. Daarnaast moet het model producten behandelen als imperfecte substituten, econometrisch geschatte parameters gebruiken en dynamiek en de invloed van seizoenen in beschouwing nemen.

Hoofdstuk 3 ontwikkelt een verbeterd partieel evenwichtsmodel en gebruikt deze om korte termijn effecten te analyseren van een afname van de binnenlandse en buitenlandse consumptie als gevolg van een voedselveiligheidscrisis en een daaropvolgende sluiting van de grenzen voor export van Nederlandse tomaten. Seizoenseffecten en marktstructuren, zoals perfecte competitie en dominantie van supermarkten zijn onderzocht. Het model analyseert de korte termijn effecten op de vraag, aanbod en prijzen in de verschillende schakels in de keten van tomaten. Met uitzondering van de dynamiek en de heterogeniteit van de producten (imperfecte substituten), neemt dit model alle wenselijke specificaties mee die zijn beschreven in Hoofdstuk 2. De resultaten tonen aan dat de sluiting van een grens grotere effecten heeft op alle schakels in de glastuinbouwketen dan een daling in de binnenlandse en buitenlandse vraag naar tomaten. Wanneer een belangrijke exportmarkt zijn grenzen sluit voor Nederlandse tomaten en op hetzelfde moment de binnenlandse en buitenlandse vraag naar deze tomaten afneemt, dan is de negatieve impact op telersprijzen drie keer groter dan het effect op supermarktprijzen. Nederlandse detailhandelaren en consumenten profiteren van de sluiting van een grens. Wanneer supermarkten meer marktmarkt hebben, zijn de Nederlandse totale welvaartsverliezen hoger. De verandering in Nederlandse welvaart is negatiever in het hoogseizoen dan in het laagseizoen.

Hoofdstuk 4 beoordeelt de verticale transmissie van prijzen in de tuinbouwketen en bekijkt of prijzen in de keten zich asymmetrisch aanpassen. Het hoofdstuk geeft een theoretische onderbouwing van de lange termijn relaties tussen prijzen en internationale handel door middel van de vector error correction en vector auto regressive modellen. Asymmetrische prijstransmissie is onderzocht met behulp van de Houck-benadering alsmede het foutencorrectiemodel. De prijzen van zaaiuien en rode paprika's, zoals waargenomen in elke schakel van de keten, zijn in het model gebruikt. Uit de impuls- responsreactie analyses blijkt dat prijzen van rode paprika relatief snel naar hun lange-termijn evenwichten terugkeren, terwijl de prijzen van zaaiuien een nieuw evenwicht bereiken na een schoksgewijze verandering in de prijs. Marktmacht van de groothandelaren beïnvloedt de reacties van prijzen van zaaiuien, maar heeft weinig of geen effect op de reacties van rode paprika prijzen. Er is geen bewijs voor een eventuele machtspositie van de supermarkten ten opzichte van de consument. De resultaten uit Hoofdstuk 4 leveren mogelijk bewijs voor asymmetrische aanpassing in de teler-groothandel en internationale handel-teler relaties in de Nederlandse zaaiui keten. Daarnaast tonen de resultaten aan de telers van rode paprika hun prijzen op de korte termijn asymmetrisch aanpassen na een schok in de supermarktprijzen van rode paprika. Telers passen hun prijs van paprika sneller aan als de supermarkt prijs van rode paprika stijgt, dan wanneer de supermarkt prijs van paprika daalt.

Hoofdstuk 5 richt zich op het producentenniveau van de keten door het gedrag en de keuzes van telers ten aanzien van hun productie, energieverbruik en investeringen in energie-gerelateerde technologie te beschrijven. Het bijzondere kenmerk dat Nederlandse glastuinbouwtelers zowel energieverbruikers als energieleveranciers zijn, is meegenomen. Het gedrag van een telersbedrijf is gemodelleerd met behulp van een combinatie van een dynamische kostenfunctie en een statische winstmaximalisatiefunctie. De optimale hoeveelheid energie voor glastuinbouwtelers is afgeleid van het verband tussen deze twee functies. Het model werd toegepast op een panel van Nederlandse glastuinbouwbedrijven gespecialiseerd in groenten en siergewassen in de periode 2001-2008. De resultaten uit dit hoofdstuk wijzen op een gematigde aanpassing (32%,) richting het lange-termijn evenwicht voor energie gerelateerd kapitaal in de Nederlandse glastuinbouw sector. Dat betekent dat het ongeveer twee jaar duurt om de helft van het verschil tussen de huidige en optimale hoeveelheid energie gerelateerd kapitaal te overbruggen. Bovendien tonen de resultaten aan dat het karakter van glastuinbouwbedrijven op de lange termijn verandert van netto elektriciteitsverbruikers naar netto elektriciteitsproducenten. Voor de Nederlandse glastuinbouw telers is productie van elektriciteit een substituut voor de productie van groenten en siergewassen. Investeren in energie-gerelateerd kapitaal draagt bij aan vermindering van het netto energieverbruik, maar verhoogt de hoeveelheid CO_2-uitstoot als gevolg van een toename van de elektriciteitsproductie.

Hoofdstuk 6 reflecteert op de gebruikte data en toegepaste methodes in dit proefschrift en bespreekt de resultaten van de verschillende hoofdstukken. Alle wenselijke specificaties voor een (glas)tuinbouw model, zoals beschreven in Hoofdstuk 2, zijn verwerkt in tenminste één van de gebruikte modellen in dit proefschrift. Toepassing van de modellen in andere ketens is mogelijk, mits de gegevens zijn aangepast aan de specifieke keten. Wat de beleidsimplicaties betreft, blijkt uit de resultaten van dit proefschrift dat er geen bewijs is voor marktmacht in de relatie tussen supermarkten en leveranciers in de Nederlandse glastuinbouw keten. De afgeleide optimale hoeveelheden van energie en energie gerelateerd kapitaal genereren een aantal nieuwe inzichten voor (duurzaam) energie beleid en de vermindering van de CO_2-uitstoot. Prikkels om te investeren in de warmtekracht koppelaars resulteren niet in een daling in de uitstoot van CO_2 emissies en de productie van glastuinbouw producten. De belangrijkste conclusies van dit proefschrift zijn:

- Bestaande partiële evenwichtsmodellen in de tuinbouw sector richten zich met name op handelsbeleid en negeren zaken als marktconcentratie en milieu (*Hoofdstuk 2*).
- De negatieve effecten op telersprijzen als gevolg van een sluiting van een exportmarkt tegelijkertijd met een daling van de binnenlandse en buiten-

landse vraag, zijn drie keer hoger dan de effecten op supermarkt prijzen in het hoogseizoen (*Hoofdstuk 3*).

- Op korte termijn profiteren Nederlandse supermarkten en consumenten van een grenssluiting voor de export van Nederlandse tomaten (*Hoofdstuk 3*).
- Dominantie van supermarkten ten opzichte van hun leveranciers heeft geen invloed op de prijzen in de daaropvolgende schakels van de keten, zelfs wanneer er een voedselveiligheidscrisis is of een grens gesloten wordt voor de Nederlandse export van een belangrijk groente. (*Hoofdstuk 3*).
- Prijsschokken in de gehele rode paprika keten nemen snel af en prijzen keren terug naar hun oorspronkelijke evenwicht, terwijl prijsschokken op groothandelsniveau in de keten van zaaiuien tot permanente prijsveranderingen leiden (*Hoofdstuk 4*).
- Telers van rode paprika passen op korte termijn hun prijzen sneller aan wanneer de supermarktprijs stijgt, maar zij passen hun prijs langzamer aan wanneer de supermarkt prijs daalt (*Hoofdstuk 4).*
- De aanpassingstermijn van Nederlandse glastuinbouwtelers is ongeveer 2 jaar om de helft van het verschil tussen de huidige en optimale hoeveelheid energie gerelateerd kapitaal te overbruggen (*Hoofdstuk 5*).
- Elektriciteitsproductie is een substituut voor groenteproductie op gespecialiseerde glasgroente bedrijven (*Hoofdstuk 5*).
- Glastuinbouw bedrijven die investeren in energie gerelateerd kapitaal voldoen aan de druk om de totale netto energie te verminderen, maar consumeren daarentegen meer fossiele energie *(Hoofdstuk 5).*

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There are advisors in all kind of areas. The people above were my main advisors for the content of my thesis, but there were some others to give me advice for administrative, private matters and so on. Anne, Karin, Jeanette & Ilona; Thanks for arranging stuff varying from airplane tickets to financial matters and copy cards!

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Curriculum Vitae *Daphne M.I Verreth*

Daphne Maria Irmina Verreth was born on November 11, 1984 in Bennekom, the Netherlands. In 2003, she finished her secondary school at the Pantarijn in Wageningen. The same year, she started the study Applied Communication Studies at Twente University. After obtaining her Bachelor degree, she switched from Twente University to Wageningen University to start with the Master Management, Economics and Consumer Studies. In January 2009, she graduated within the specialization Business Economics.

After graduation, Daphne started as a PhD student at the Business Economics Group at Wageningen University. During this period, Daphne followed different economics and econometrics courses, joined international seminars and conferences and became a visiting scholar for 2.5 months at UC Davis, California (USA).

Since April 2013 Daphne works as advisor Regulatory affairs at Enexis, a distribution system operator, in the Netherlands.

Daphne Verreth
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Wageningen School of Social Sciences

DESCRIPTION	Department/ Institute	YEAR	ECTS[1]
General courses			
Introduction course	WASS[2]	2009	1.5
Effective behaviour in your professional surroundings	WGS	2011	0.7
Writing Research Proposal	WASS	2010	1
Techniques for writing and presenting a scientific paper	WGS	2009	1.2
Scientific Exposure			
"Impacts of CO2 emission policies in the Dutch greenhouse sector"	EAAE[2] seminar, Crete, Greece	2010	1
"Dynamic adjustments in Dutch greenhouse sector due to environmental regulations"	EAAE seminar, Ancona, Italy	2011	1
"Price transmission, market power and trade: a case study in the Dutch agri-food chain"	EAAE congress, Zurich, Switzerland	2011	1
"Dynamic and Static behaviour with respect to energy use and investment of Dutch greenhouse firms"	AAEA[2], Seattle USA	2012	1
Discipline-specific courses			
Econometrics (AEP 21306)	WUR[2]	2009	6
Advanced Econometrics (AEP 60306)	WUR	2009	6
Economic Models (AEP 30806)	WUR	2009	6
Theories and Models in Environmental Economics (ENR 30306)	WUR	2010	6
Advanced GAMS modelling	WUR	2012	0.5
International Trade	NAKE[2]	2009	3
Advanced Industrial Organisation – Empirical	NAKE	2010	6
Time Series	NAKE	2011	6
Summer course Industrial Organisation + Game Theory	University of Crete	2009	1
Business Economics Group PhD Meetings	WUR	2009-2013	4

Teaching and supervising activities			
Teaching Financial Investment Analysis	Van Hall Larenstein	2009-2012	4
Career-related competences / personal development			
PhD competence assessment		2009	0.3
Career Orientation		2012	1.5
PhD Council at WASS Graduate School (including chair)	WASS	2009-2011	2
TOTAL			**60.7**

[1] One ECTS is equivalent to 28 hours of course work

[2] WASS= Wageningen Graduate School of Social Sciences; EAAE= European Association of Agricultural Economics; AAEA= Agricultural & Applied Economics Association; WUR= Wageningen University and Research Centre; NAKE=Netherlands Network of Economics

Colophon

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